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United States Centennial Commission.

INTERNATIONAL EXHIBITION,
1876.

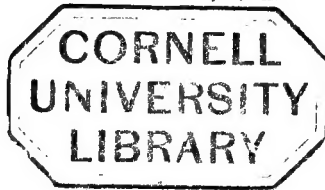
REPORTS AND AWARDS

GROUP XV.

EDITED BY
FRANCIS A. WALKER,
CHIEF OF THE BUREAU OF AWARDS.

PHILADELPHIA:
J. B. LIPPINCOTT & CO.
1877.

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SYSTEM OF AWARDS

[*Extract from Circular of April 8, 1876.*]

Awards shall be based upon written reports attested by the signatures of their authors.

The Judges will be selected for their known qualifications and character, and will be experts in departments to which they will be respectively assigned. The foreign members of this body will be appointed by the Commission of each country and in conformity with the distribution and allotment to each, which will be hereafter announced. The Judges from the United States will be appointed by the Centennial Commission.

* * * * *

Reports and awards shall be based upon inherent and comparative merit. The elements of merit shall be held to include considerations relating to originality, invention, discovery, utility, quality, skill, workmanship, fitness for the purposes intended, adaptation to public wants, economy and cost.

Each report will be delivered to the Centennial Commission as soon as completed, for final award and publication.

Awards will be finally decreed by the United States Centennial Commission, in compliance with the Act of Congress, and will consist of a diploma with a uniform Bronze Medal, and a special report of the Judges on the subject of the Award.

Each exhibitor will have the right to produce and publish the report awarded to him, but the United States Centennial Commission reserves the right to publish and dispose of all reports in the manner it thinks best for public information, and also to embody and distribute the reports as records of the Exhibition.

ORGANIZATION AND DUTIES OF THE JUDGES.

[*Extract from Circular of May 1, 1876.*]

Two hundred and fifty Judges have been appointed to make such reports, one-half of whom are foreigners and one-half citizens of the United States. They have been selected for their known qualifications and character, and are presumed to be experts in the Groups to which they have been respectively assigned. The foreign members of this body have been appointed

by the Commission of each country, in conformity with the distribution and allotment to each, adopted by the United States Centennial Commission. The Judges from the United States have been appointed by the Centennial Commission.

To facilitate the examination by the Judges of the articles exhibited, they have been classified in Groups. To each of these Groups a competent number of Judges (Foreign and American) has been assigned by the United States Centennial Commission. Besides these, certain objects in the Departments of Agriculture and Horticulture, which will form temporary exhibitions, have been arranged in special Groups, and Judges will be assigned to them hereafter.

The Judges will meet for organization on May 24, at 12 M., at the Judges' Pavilion. They will enter upon the work of examination with as little delay as practicable, and will recommend awards without regard to the nationality of the exhibitor.

The Judges assigned to each Group will choose from among themselves a Chairman and a Secretary. They must keep regular minutes of their proceedings. Reports recommending awards shall be made and signed by a Judge in each Group, stating the grounds of the proposed award, and such reports shall be accepted, and the acceptance signed, by a majority of the Judges in such Group.

The reports of the Judges recommending awards based on the standards of merit referred to in the foregoing System of Awards, must be returned to the Chief of the Bureau of Awards not later than July 31, to be transmitted by him to the Centennial Commission.

Awards will be finally decreed by the United States Centennial Commission, in compliance with the Act of Congress of June 1, 1872, and will consist of a special report of the Judges on the subject of the Award, together with a Diploma and a uniform Bronze Medal.

Upon matters not submitted for competitive trial, and upon such others as may be named by the Commission, the Judges will prepare reports showing the progress made during the past hundred years.

Vacancies in the corps of Judges will be filled by the authority which made the original appointment.

No exhibitor can be a Judge in the Group in which he exhibits.

An exhibitor, who is not the manufacturer or producer of the article exhibited, shall not be entitled to an award.

The Chief of the Bureau of Awards will be the representative of the United States Centennial Commission in its relations to the Judges. Upon request, he will decide all questions which may arise during their proceedings in regard to the interpretation and application of the rules adopted by the Commission relating to awards, subject to an appeal to the Commission.

A. T. GOSHORN,
Director-General.

SYSTEM OF AWARDS.

[*Extract from Director-General's Address to Judges, May 24, 1876.*]

“The method of initiating awards which we have adopted differs in some respects from that pursued in previous exhibitions. In place of the anonymous verdict of a jury, we have substituted the written opinion of a Judge. On this basis awards will carry the weight and guarantees due to individual personal character, ability, and attainments, and to this extent their reliability and value will be increased. It is not expected that you will shower awards indiscriminately upon the products in this vast collection. You may possibly find a large proportion in no way raised above the dead level, nor deserving of particular notice. The standard above which particular merit worthy of distinction begins is for you to determine. In this regard I have only to express the desire of the Centennial Commission, that you should do this with absolute freedom, and when you meet with a product which you consider worthy of an award, we desire you to say, in as few words as you may deem suitable, why you think so.

“This, gentlemen, is all we ask of you in the Departments of Awards. Opinions thus expressed will indicate the inherent and comparative merits, qualities, and adaptations of the products,—information which the public most desires.

“Elaborate general reports and voluminous essays, though of great value as sources of general information, give little aid in determining the reliable or intrinsic merits of particular, individual products.

“The regulations which have been published divide the work of awards into three parts:

“1st. The individual work of the Judges.

“2d. The collective work of the groups of Judges.

“3d. The final decisions of the United States Centennial Commission in conformity with the acts of Congress.

“Each award will thus pass three ordeals, which, doubtless, will be ample and satisfactory.”

GROUP XV.

JUDGES.

AMERICAN.

DANIEL STEINMETZ, Philadelphia, Pa.

CHAS. STAPLES, JR., Portland, Me.

GEORGE L. REED, Clearfield, Pa.

JOHN D. IMBODEN, Richmond, Va.

FOREIGN.

J. BAIN, Lord Provost of Glasgow, Great Britain.

DAVID MCHARDY, Great Britain.

JULIUS DIEFENBACH, Germany.

GROUP XV.

BUILDERS' HARDWARE, EDGE TOOLS, CUTLERY, ETC.

1. CLASS 280.—Hand tools and instruments used by carpenters, joiners, and for wood and stone in general. Miscellaneous hand tools used in industries, such as jewelers', engravers'.

2. CLASS 281.—Cutlery—knives, penknives, scissors, razors, razor-strops, skates, and implements sold by cutlers.

3. CLASS 283.—Metal hollow-ware—ornamental castings.

4. CLASS 284.—Hardware used in construction, exclusive of tools and implements,—spikes, nails, screws, tacks, bolts, locks, latches, hinges, pulleys. Furniture fittings; ships' hardware. (For carriage hardware, see Group XVII.)

5. Horseshoes and horseshoe nails.

6. Malleable iron castings.

7. Stove polish.

GENERAL REPORT
OF THE
JUDGES OF GROUP XV.

INTERNATIONAL EXHIBITION,
Philadelphia, 1876.

PROF. FRANCIS A. WALKER, *Chief of Bureau of Awards :*

SIR,—I have the honor to transmit herewith the report of the
Judges of Group XV., which I trust will prove satisfactory.

Very respectfully,

DANIEL STEINMETZ, *Chairman.*

GROUP XV.

BUILDERS' HARDWARE EDGE-TOOLS, CUT-
LERY, ETC.

SAFES, SAFE-LOCKS, ETC.

BY DANIEL STEINMETZ.

This exhibit comprised a very important interest, and presented a very extensive and creditable display, having in all twenty-five depositors, of whom nine were foreign.

Between the foreign and domestic manufactures there is a marked contrast. While the foreign products are in some instances exceedingly well fitted, and finished in a workmanlike manner, there is but little manifestation of an intention to give protection from intense heat, or from the ingenuity of an accomplished burglar—qualities so largely prominent in the domestic products. It may be, and doubtless is, to a considerable extent, the case that the opportunities are not so frequently supplied, in the densely-populated cities and towns of the Old World, either for extensive fires or for long-continued burglarious operations as are found in this country, and therefore the same extent of protection in these particulars is not needed, but it is quite certain that, with our views and experience, great change would have to be made to adapt the foreign safes to popular use in this country.

In American safes the greatest care has been taken to thoroughly protect by the use of every known effective non-conductor as a safeguard from intense heat, and also by the adoption of layers of steel and iron and other hard material, either riveted and welded together in almost every conceivable manner or dependent upon its native strength alone, made in various forms of depository, to secure from the attacks of burglars.

Generally, what appears to be a large receptacle will be found to

be so supplied by layers of metal, deposits of "fire-proof" material, patent locks, bolts and bars, as to have but a comparatively small interior space in which to deposit the articles to be secured.

As it is generally the case, however, that articles deposited in safes are valuable, and require but little room, this occupation of space is not deemed objectionable where safety is secured, but if a larger space is desired it is provided in a safe of larger size, which can be obtained at a proportionate advance in price.

Very great ingenuity has been shown in the invention of locks, prominent among which appears what is called the "chronometric" or time lock. Acting automatically, it prevents the opening of the safe between given hours, when the director desires it to be closed, thus positively preventing the opening of the safe by any one, even though in possession of every detail of the mechanism of both lock and safe. The hour predetermined for opening must arrive, when the chronometric attachment removes the obstruction, and then only can the safe be unlocked. This attachment is made in the interior of the safe, and therefore cannot be controlled except by force, which, of course, could not be applied if proper protection was given. This provision affords protection to country banks and bankers, whose cashiers are liable to be attacked by burglars, taken to the bank, and compelled to open the vaults or supply the means to do so. As, when the chronometric attachment is used, the custodian of the safe cannot open it out of hours for any purpose, the burglar must either do what he can to break in or wait for the time for unlocking, which would probably be quite an unsafe hour for him.

The safes now made are not only up to the improvements of the intelligence of the hour in point of substantial service, but are even elegant in their finish and ornamentation. Some are so combined with the patterns and designs of household furniture as to make them beautiful and attractive in the parlor or drawing-room, at a cost not unreasonably above articles of good quality made by the cabinet-maker for ordinary service.

The bankers' or business safes are, however, of the greatest importance to the welfare of the community. In these the increasing dexterity of the burglar, armed with the most improved drills, wedges, and levers, and supplied with air-pump, blow-pipe, and concentrated explosives, has kept active all the inventive powers at the command of safe-makers. So we have constantly contending the burglar and the safe-maker,—the first aiming to prey upon the community, the other to defeat this aim. Thus, as burglars apply improved tools and materials to open the locks or penetrate the walls

of the safe, the safe-maker must stand prepared to supply a preventive by increasing the resistive power of his safes.

Viewing the best American safes, with their massive casework, heavy bolts, and ingenious lock-construction, we find a wonderful contrast with the American safe of fifty years ago.

What was then called a safe was little more than a box with a hollow frame of heavy sheet-iron, between the outer and inner walls of which was deposited either (so-called) asbestos, plaster, or some other preparation deemed sufficient for protection in an ordinary fire. It was commonly made with corner- and edge-bands, which were riveted with ordinary rivets, and the whole outer surface of the safe, except the bottom, laid at regular intervals with cast-iron knobs, to add to the appearance of weight and strength. The locks were of the plainest character; and it is believed an expert burglar of the present day could enter them with very ordinary tools in a very few minutes. One of these "safes" is occasionally brought to light at public sale, where they are so little esteemed for their powers of protection as to make their price not greatly above that of a wooden box of similar dimensions.

Urgent solicitations were made that experimental tests should be had whereby the power of resistance to fire and burglars might be established. Inasmuch as no provision was made to this end by the Commission, and as all such tests give rise to charges of unfairness, and are seldom, if ever, satisfactory to any of the parties interested, it was determined to make none, and to confine the investigation to the merits of each deposit as it appeared in the Exhibition.

EDGE-TOOLS, CUTLERY, POLISHING AND BURNISHING MATERIALS, METAL HOLLOW WARE AND ORNAMENTAL CASTINGS, AND HARDWARE.

BY DAVID MCHARDY.

(Extract from the Report to the British Commission.)

The following table shows the number of the exhibitors in the different classes of Group XV. to which this report refers. As might be expected, the United States are by far the best represented country. Then comes France, between which and the United States there have been for the last hundred years many friendly associations. Canada and Great Britain and Sweden are the best represented of the remaining countries.

	EDGE-TOOLS USED BY CARPENTERS, JOINERS, ETC.; MISCELLANEOUS HAND-TOOLS.	CUTLERY, KNIVES, SCISSORS, RAZORS, SKATES, AND IMPLEMENTS SOLD BY CUTLERS.	EMERY AND SAND-PAPER, POLISHING POWDERS, BURNISHING TOOLS, ETC.	HOLLOW WARE AND ORNAMENTAL CASTINGS, ETC.	METALLIC PRODUCTS.	BURGULAR AND FIREPROOF SAFES, SAFE LOCKS, ETC.
CLASSES.....	280	281	282	283	284	284
United States.....	70	34	3	14	9	13
Great Britain	5	7	.....	1	4	1
Canada.....	23	4	.....	.....	4	1
France	7	13	5	12	1	1
Germany.....	2	4	1	3	1	.....
Austria.....	3	1	.....	2	1	.....
Switzerland.....	1	1	.....	.....	1	.....
Belgium.....	.....	.....	.....	.....	4	1
Netherlands.....	1	1	.....	.....	1	.....
Sweden.....	6	.....	.....	.....	.....	1
Norway .....	.....	1	.....	2	2	2
Italy	1	1	1	3	2	.....
	124	72	10	37	30	20
Total.....293						

CLASS 280.—EDGE-TOOLS AND MISCELLANEOUS HAND-TOOLS. .

It will be seen from the table that more than half of the exhibitors belong to the United States.

The natural advantages which America possesses in the products of her mines place her in a better position to obtain a high quality in the materials out of which the greater part of the exhibits in this class are made, than is to be found in most of the other countries which were represented at Philadelphia. The remarkably fine quality of the iron ore, the care taken in its reduction, and the skill displayed in the manufacture, both of iron and steel, by American firms, result in their productions' occupying an enviable position before the world.

AXES.—Among edge-tools a front place must be given to the axe. There are few countries where the axe has been so much employed or more severely tested than in the United States. The clearing of the forests from so wide an area must have shown to the settlers very correctly not only what was required in the quality of the axe, but what was the best form in which it should be made.

The American axe has for many years displaced the axes imported from Britain, and these axes are now used exclusively throughout the

United States, and in other countries, including Canada, where their excellence has stimulated several Canadian firms to manufacture for themselves axes of a similar character. American axes are now imported into this country, and are found, for the purpose of clearing land, more efficient than the tools made in the old shape at home. The great proportion of the American axes are manufactured by welding in the steel into the axe after the eye has been partially formed. This mode requires very careful attention and skill, to prevent the steel from being injured in its quality; but the best American axe is made out of a solid piece of cast-steel, and the eye is punched out of the solid. These axes are superior, as the steel is not by this plan injured in welding; but there is no difference in the shape of the tool.

In the original form of the British axe the section would show the eye to be the thickest part of the tool, tapering slightly towards the crown; below the eye the body of the axe is thinned considerably, tapering down to the cutting edge. In the American axe, the body is slightly tapered to the crown, and from the eye the body of the axe is kept full and tapered down to the cutting edge.

In felling trees the American axe is more easily worked; its shape enables it to be more easily drawn out after the blow is given, and the body of the axe, being much firmer, is not liable to twist in working. American axes made by welding in the steel had their cutting quality severely tested by striking a steel block several times without turning the edge. The demand for this class of axes is enormous, and the number of makers consequently very large, so that we are not surprised to find many exhibitors of the same style of tool with little difference in the external appearance. In most cases the exhibits (which were taken from stock) were polished in a superior manner, and some of them were fitted with handles, so that an opportunity was afforded of putting their quality to the test as explained above.

Among the more extensive exhibitors were MESSRS. COLLINS & Co., *New York, N. Y.*, whose display was one of the largest and most complete in the section of edge-tools. It comprised most of the varieties and qualities that are in use, all of excellent workmanship. They exhibited, also, a number of picks, from five to seven pounds, for mining purposes, with adze-eyes, polished and plain.

The DOUGLAS AXE COMPANY, *Boston, Massachusetts*, also showed a large assortment of axes, hatchets, and adzes, with patent eyes; also, picks for railway purposes, of the same variety as the exhibit of Messrs. Collins, and good specimens of workmanship.

YERKES & PLUMB, *Philadelphia, Pennsylvania*, exhibited a select variety of adzes, cast-steel hammers for machinists and engineers, smiths' hammers, hand and fore hammers, and heavy picks with strong eye for general use. They are all of a high class, the shape having been carefully arrived at, and the manufacture excellent.

PICKAXES, ETC.—The HARDY PATENT PICK COMPANY, LIMITED, *Sheffield, England*, exhibited a large number of cast-steel picks, specially made for mining operations; the picks are made of an extra fine quality of cast-steel. The specialty of the pick consists in the mode by which any number of picks can be fitted to one handle.

DATES PATENT STEEL COMPANY, *Toronto, Canada*, exhibited a large variety of tools for different industries, viz., cast-steel drawing-knives of different varieties, cast-steel adzes for the carpenter and the cooper trade, lath-splitting axes for plasterers, double-ended axes or mattocks for clearing roots, and axes for forest use of the American pattern. The company make their own steel, and use petroleum in the process.

JOSEPH WARNOCK & Co., *Galt, Ontario*, exhibited cast-steel axes, the axes being forged entirely from cast-steel, and the eye of the axes punched out of the solid bar, as already described. In addition to a variety of axes of this description, the company manufacture a large assortment of coopers' tools, adzes, drawing-knives, all of excellent workmanship. The two exhibitors last mentioned were both considered worthy of a silver medal granted by the Canadian Commission to exhibitors from the Dominion.

An assortment of strong lumbermen's tools was exhibited by PETER ROBERTSON, *Ottawa, Ontario*. They consist of long ash handles, about six feet, with strong hoops at the lower end, which are further strengthened by iron sockets and sharp points. At some distance from the point an eye with a long hook is firmly fixed through the handle, and this is used for canting the trees. There are a number of these required, and the exhibit shows how carefully they have been made. A number of dogs and rings, and other fixings and shackles for rafts, are of the same quality, and well suited for the description of work. The exhibit also contained a number of cast-steel chisels and puncheons for working granite, short picks with handles, and single axes for the same description of work. The specimen of smith-work was good. The chisels and puncheons are of $\frac{7}{8}$ -inch octagon cast-steel, and 7 inches long. The picks are made from a good quality of iron, $2\frac{1}{4}$ inches square at the eye, and

tapered to a sharp point; the steel is of the best blister or hoop L quality, and is frequently renewed.

THOMAS MOORE, *Cooksville, Ontario*, exhibited a large assortment of tool-handles, made of clean ash, both round and oval; they are beautifully turned and finished for the several forms required, viz., axes, hammers of different sizes, steel forks, shovels, etc. The wood is of the lightest description, and in shovels, forks, or instruments for farm or laboring use must be of considerable advantage in lessening the weight of the tool.

The Dominion bronze medal was awarded by the Canadian Commissioners to P. Robertson and Thomas Moore.

THE D. R. BARTON TOOL COMPANY, *Rochester, New York*, exhibited a fine display of cast-steel hammers, with handles, for carpenters, joiners, and for general use. They are made with adze-eye sockets for the handles, and well-formed claws clean cut inside. A variety of carpenters' and joiners' chisels and other tools for that trade are of excellent workmanship.

GEORGE SELSOR & Co., *Philadelphia, Pennsylvania*, exhibited a varied assortment of hammers, edge and railroad tools of good workmanship, and in addition a coffee-mill of a new construction, which the patentee calls the "Treble Anti-friction Coffee-Mill." The barrel is formed into two flat cones, the upper is cut rough, and the lower cut with a finer pitch to suit any degree of fineness required. The case inclosing the barrel is of iron, in two parts, the cutting inside both being of the same pitch as the barrel which is inclosed. The spindle rests on a steel stud in the centre of the lower case, and prevents any friction in regulating the fineness of the coffee. This is done by a screw on the top of the spindle. The specialty consists in being able to regulate the degree of fineness when the mill is in motion. All the cutting parts are hardened, and the patentee states that it grinds "as fine as the best French mills and with much greater rapidity." This was tried for different degrees of fineness, and the results were very satisfactory in reference to the time employed and the quality of the grinding. A suitable mill for a family, with polished poplar box $7\frac{3}{4}$ inches square, and Britannia hopper, costs, in Philadelphia, \$1.25.

Although only a few exhibitors have been referred to above it will be understood that the number in the class was very large, and that it was with the greatest difficulty that any difference in the quality of the articles displayed could be discovered.

SAWS.—If the axe occupies an important position in usefulness, undoubtedly the saw cannot be considered as a less important tool

in the workshops of a civilized country. The hand-saw has for ages been constructed on two types,—first, the broad flat saw with a handle at the end, as used in Britain; and, second, a thin steel band stretched from two points, such as is used by Frenchmen and Chinese. In America both kinds are used, each kind being employed in the class of work to which it is naturally best suited. In the ordinary workshops the circular and the band saw are now used extensively and cause immense saving in time and labor by the manner in which curved work is so quickly executed.

The most extensive exhibit of saws was by MESSRS. HENRY DISSTON & SONS, *Philadelphia, Pennsylvania*, consisting of every variety, from the large circular saws for machinery to the smallest band saw of $\frac{1}{8}$ inch in breadth. Some of the largest circular saws have separate steel teeth inserted in the circumference, so fitted that the friction in the operation does not loosen their hold or destroy their efficiency. The handsaws were carefully examined, not only for hardness of the steel but for the quality of the temper. Several handsaws were tried by striking their backs upon a bloom of cast-steel without marking them in the least degree, and the same saws were bent until the point touched the wooden handle, and when let free sprang back to their former shape, perfectly straight.

Disston & Sons have made improvements in the form of the handles, and in the mode of fixing them to the saw; there is also an improvement in the shape of the blade, by which it is made lighter and more convenient by giving it a greater taper to the point. The smaller saws with brass and iron backs were of excellent workmanship. In addition to the different varieties of saws they exhibited an assortment of steel squares and rules, correctly graduated, and marked by figures beautifully finished; also an assortment of levels for workmen, with finished stocks. This firm is one of the largest in America; they employ 1200 hands, and manufacture their articles from Sheffield steel, using up all their waste cuttings.

It is creditable to the Dominion of Canada to have such a firm as that of MESSRS. R. H. SMITH & Co., *St. Catherine, Ontario*, representing the growing manufactures of the Province. Their case contained (besides the large circular saws for machinery) a great display of all descriptions of cast-steel saws, frame saws, hand and tenon saws, and a variety of the smaller sizes of carpenters' tools. The steel used by this firm is stated to be Jessop's. The quality of the tools is excellent, and the workmanship superior. This firm obtained the gold medal of the Canadian Commission for the great extent and high quality of their exhibit.

THE AMERICAN SAW COMPANY, *Trenton, New Jersey*, exhibited an extensive assortment of machine and handsaws; the latter showed great excellence in the manufacture by the elasticity and the workmanship of the tools.

MR. EBEN MOODY BOYNTON, *New York*, exhibited a good selection of saws of cross-cut and other varieties of considerable extent; they are made out of the best cast-steel, and well finished; also ice and dray saws. The specialty of this exhibit was a cross-cut saw, which is named "the Patent Lightning Saw," from its performances. Its novelty is in the shape of the teeth, which are different from those of an ordinary cross-cut saw. By the form of the teeth the saw can cut both by the forward and backward motion. An experiment was made in the presence of two officials of the effect of this form of teeth, when two men cut through a 16-inch log in 17 seconds. This firm also showed a new form of pruning-saws with cutting-teeth on both edges; they are made from 14 to 22 inches long, and are said to be much more convenient than the common form.

MR. ANDREWS, of *Williamsport, Pennsylvania*, is the maker of a flat handsaw, which has the handle considerably strengthened by the simple means of allowing the steel of the saw to pass right to the end as a flitch between the wooden pieces of the handle, to which it is firmly riveted. The same maker has also a simple and clever saw frame, by which the saw is kept always properly strained without the means of a brace.

The exhibitors in this class of goods were chiefly from the United States; Great Britain had not a single representative, although for years Sheffield supplied not only our own country but nearly all the world. It will be seen from what has been already described that this monopoly remains with us no longer, and it is to be hoped that the knowledge of this fact will rouse up the manufacturers in England to try and achieve, as far as may be possible in the present circumstances, a position of equal distinction to that held by their predecessors.

AUGERS, ETC.—In remarking upon tools generally employed in the manufacture of wood, it will be necessary to notice the class used in the heavier branches of the building trade and those that are required in the workshops of joiners, carpenters, cabinet-makers, turners, carvers, and by amateurs and others. In this section the auger, on account of its many uses in the arts, may be considered the most important exhibit. The grand display of examples and the number of exhibitors bore testimony to this fact. The exhibits, as we have

noticed in other classes, are for the most part manufactured in the United States, the number from other countries being very limited.

Great improvements in the qualities of augers have been made during recent years, as shown in the many varieties now in general use. The old shell auger is very rarely employed, and the screwed form of the tool has taken its place. The augers exhibited at Philadelphia were remarkable for the accuracy of the twist, the various forms of the cutters, the quality of the steel, and the fine finish of the twist and polish, all showing a degree of perfection not previously reached. An opportunity was afforded of testing the quality of two varieties, in boring a piece of pine and a piece of walnut by an auger with Jennings's patent bit, and one with a gouge-lip bit, both of 14.16 diameter. The result was nearly the same in the cross boring, but in the end wood, specially of the pine, it was agreed, after a fair trial, that the gouge bit made the cleanest hole.

A class of augers was shown different in the form of the screw, and named "Single Twist Bits," but they are more expensive and not so generally used as others.

The number of turns of screw varied. In the augers which were tested the screw did not exceed 6 turns. Smaller sizes have from 6 to 8 turns, while a variety called car bits, used principally by coach-builders, have the twist extended to 16 turns. These car bits are more expensive than the common gouge-lip bit of the same diameter. A very fine exhibit of them was shown in the Machinery Hall at the back of Messrs. Disstons' display.

There was a limited show of augers named "Tap Borers," different in shape from any of the other forms, and used in making wooden pipes. They are made hollow, of steel, and fixed to an iron socket-head for the handle, and have a long taper with screw point. The width at the shoulder, where the iron socket is attached, measures from 6 to 8 quarters of an inch.

For boring large-sized holes, an instrument named the "Expansive Boring Bit" was shown. It consists of a steel spindle with screwed point like the auger, and has a plate about two inches long formed behind the screw, and about one inch broad. A cutter is formed on one of the edges, and there is a steel knife with oblong hole to admit a steel screw to fix it to the flat part of the spindle at any distance required to form the exact size of the hole. The knife has a sloped point set at any angle, as the plane iron.

American augers, such as "Jennings's Spur Auger Bits," from the manufactory, Deep River, Connecticut, are in use in Great Britain generally,—indeed, they are found in the northern parts of this coun-

try; they are somewhat more expensive than home-made augers, but are preferred in many instances on account of the excellence in the workmanship and quality of the tool. Altogether, the Philadelphia Exhibition has fully established the reputation of American augers.

In the section of tools comprising cast-steel chisels, gouges, turning and carving tools, there was a good exhibition. The larger sizes for heavy work are furnished with sockets for the handle, while the smaller descriptions are made with a shoulder and tang. In the best tools, the shoulder is made out of the solid. A very large assortment of this section was shown by MESSRS. BUCK BROTHERS, *Riverlin Works, Milbury, Massachusetts*. Tang tools of considerable variety were exhibited; they are well made, and the finish of the turning tools and the plane irons is of a superior character.

The D. R. BARTON TOOL COMPANY, *Rochester, New York*, exhibited a good selection of mechanics' tools of different kinds, of good workmanship; the smaller size have been turned out with a very neat appearance.

A case of scientific tools for brass, iron, and wood turnings were exhibited by MESSRS. WARD & PAYNE, steel manufacturers, *Sheffield, England*; they showed, also, all the varieties of tools used by carpenters, millwrights, masons, and bricklayers, all of a high class. Their display further embraced a superior assortment of cast-steel carving and turning tools for iron, brass, ivory, and wood gravers for die-sinking; the firm also manufacture sheep-shears of excellent quality.

The STAR TOOL COMPANY, *Middletown, Connecticut*, in addition to the usual variety of carpenters' tools, exhibited a select assortment of squares with rosewood stocks, and steel blades accurately graduated to different divisions of an inch; also, bevel stocks made in the same style, flexible steel rules to 36 inches, and a variety of steel calipers; the whole of this exhibit was very attractive, and the prices are moderately charged; a 12-inch square being only \$1.00.

An extensive collection of tools from MESSRS. J. B. ADDIS & SONS, edge-tool manufacturers, *Sheffield, England*, comprised sets of tools for carving stone and wood in all the varieties; they are of the finest cast-steel and made in a thoroughly first-class style. Turning tools of the same quality for ivory, iron, brass, and wood were also shown, as well as a good collection of the usual carpenters' tools.

A most interesting exhibit was that of DARLING, BROWN, & SHARPE, *Providence, Rhode Island*. It consisted of a varied selection of instruments of precision, such as steel squares, rules, calipers. The

extreme perfection with which the scales were graduated was charming, and their vernier caliper reads to $\frac{1}{1000}$ of an inch. Such an instrument must be highly valued by the intelligent workman.

PLANES, ETC.—A great part of the marked advance in the improvement of workmen's tools which has been made during recent years is justly due to the inventive genius of American citizens, and in the section of planes exhibited in the Centennial Exhibition this is fully confirmed by an important change in the structure of the tool.

The planes manufactured in Great Britain and in other countries fifty years ago were formed of best beechwood; the plane irons were of steel and iron welded together; the jointer plane, about 21 inches long, was a bulky tool; the jack and hand planes were of the same materials. Very little change has been made upon the plane in Great Britain, unless in the superior workmanship and the higher quality of the plane iron. American planes have now found their way into Great Britain, and it will be seen whether the old type is to be preferred, or whether a fair trial is to be granted to the manufactures of the New World.

The American plane is constructed with a skeleton iron body, having a curved wooden handle; the plane iron is of the finest cast-steel; the cover is fitted with an ingenious trigger at the top, which, with a screw below the iron, admits of the plane iron being removed for sharpening and setting without the aid of the hammer, and with the greatest ease. The extensive varieties of plane iron in use are fitted for every requirement; a very ingenious arrangement is applied to the tools for planing the insides of circles or other curved works, such as stair-rails, etc. The sole of the plane is formed of a plate of tempered steel about the thickness of a handsaw, according to the length required, and this plate is adapted to the curve, and is securely fixed at each end. With this tool the work is not only better done but in less time than formerly. In some exhibits the face of the plane was made of beech or of other hard wood, secured by screws to the stock, and the tool becomes a hybrid, all the other parts remaining the same as in the iron plane.

A few examples of the old type of beech plane were shown, remarkable for the superior quality of the workmanship, and were mounted with polished iron starts. The finish of the iron planes was different according to requirement; some were ground and japanned, others polished, and some nickel-plated, the higher finish being on the smaller sizes. It was stated by one firm that their output had amounted to 80,000.

There were twelve exhibitors to a greater or less extent of first-class workmanship, among whom the following were included: the METALLIC PLANE COMPANY, *Auburn, New York*; the MIDDLETOWN TOOL COMPANY, *Middletown, Connecticut*; BAILEY, LEONARD, & Co., *Hartford, Connecticut*; THE SANDUSKY TOOL COMPANY, *Sandusky, Ohio*.

Some of the above exhibited wooden bench- and hand-screws, squares, levels, etc. In several exhibits of carpenters' tools there were a variety of braces and bits, very good specimens of tool-making. There were a few examples of a different construction, having an expansive chuck for the bit. The steel jaws were jointed to a screwed end which fitted into a screwed "sleeve" or socket. The jaw would admit different sizes of bits in the squares, and when placed the sleeve was screwed on to the holder, and the bit remained quite secure. The exhibits of the MILLER'S FALLS COMPANY, *Masachusetts*, and WM. A. IVES & Co., *New Haven, Connecticut*, contained beautiful examples of the expansive brace; the prices were stated at from \$5 to \$8. The several exhibits in the section formed an attraction to the numerous artisans who visited the Centennial Exhibition from the United States and other countries.

VISES.—It may be proper, before closing the section of hand-tools, to select a few used in manufacture of iron, such as the vise. The usual construction of the common vise is well understood; the movable side is jointed to the standard from 15 to 18 inches below the level of the jaw. The consequence is that when opened a few inches the jaws are not on the same plane, and, beside this inconvenience, the constant injury to the screw and box through carelessness is expensive. Several examples of vises constructed on new principles were exhibited.

The STEPHENS PATENT VISE COMPANY, *New York, N. Y.*, showed an extensive selection of parallel vises with width of jaw from 2 inches up to $6\frac{1}{2}$ inches. The tool is cast in two separate pieces with steel facings; the front jaw is attached to a parallel bar, planed and correctly fitted to a recess in the main body of the tool, and may be moved forward and backward with ease. On the right edge of the bar a steel rack is inserted cut with ratchet teeth, which are acted on by a handle in connection with an arrangement of a cam and toggle. The parallel bar is pulled out to the extent of 10 inches (in the larger sizes) at once, and closed by the hand upon the article to be held; the handle is then pulled tight, and whatever is in the vise is held many times more firmly than is possible with any other vise. Upon the lower

side there is a swivel arrangement which admits of the vise being turned to any angle required. This vise has been well tried, and seems to bear out all that the patentee claims.

SIMPSON'S Adjustable Parallel and Swivel Vise is worked in the same manner as the common screw vise; at the same time the jaws can be instantly opened or closed the full length by one movement of the hand without the use of the screw. This vise is well proportioned, with steel-faced jaws, the screw and the ingenious mechanism are concealed in the interior, and are therefore free from injury by dirt or filings, and as the screw is only used to give the grip they wear exceedingly well.

FILES.—It is not easy to institute a comparison in the quality of this class of tools; the cutting, which is the only element that can be seen, is not sufficient evidence to fix a true value of the worth of the tool. Sheffield held for many years the front place in the manufacture of files; this did not altogether depend upon the excellence of the cutting, but mainly on the high quality of the cast-steel, and on the skill shown in the process of tempering.

There were at Philadelphia 16 exhibits, and of this number there were from manufacturers of the United States 11; Sweden, 5; Great Britain, 2; Switzerland, 3; France, 1; Belgium, 2; total, 24.

The files were in two distinct classes, viz., machine- and hand-made.

Only two of the latter class were shown, by McCaffrey & Bro. and Alexander Krumbhaar, both of *Philadelphia, Pennsylvania*. Their exhibits contained several varieties; the cutting was executed with accuracy, and showed considerable skill.

An exhibit near the east end of the Machinery Hall contained excellent examples of massive files for engineering purposes, from 18 to 20 inches long; the workmanship, considering the breadth of the flat hand files, was exceedingly good; the exhibit was highly creditable.

The Western File Company, *Beaver Falls, Pennsylvania*, and the Nicholson File Company, *Providence, Rhode Island*, were placed beside each other; the exhibits contained extensive assortments of machine-made files of every description; the cutting was well executed in the larger and smaller sizes; the smooth files were beautifully made. The round files of the Western File Company were executed in a superior style.

The exhibit of Hawksworth, Wilson, Ellison, & Co., *Sheffield, England*, was very extensive; one of the divisions contained files

which were of first-rate quality, maintaining the reputation of the firm in Sheffield manufactures.

LIMET-LAPAREILLE & Co., *Paris, France*, showed two cases of various sizes. They were principally intended for machinists, and were very well adapted for their purpose.

A very fine exhibit from A. DE LAMBERT, *Liège, Belgium*, of some extent, contained a great variety of fine cast-steel files of small size for jewelers and watchmakers. Some of the examples did not exceed $2\frac{1}{2}$ inches; when examined through a glass, there was evidence of a skillful hand and of an educated workman.

Files somewhat of the same type were exhibited by LOUIS FRANÇOIS GROBET, *Vallorbe, Ct. Vaud, Switzerland*; they formed a very creditable display.

I. MARC SERVET FILS, *Geneva, Switzerland*, VAUTIER & SONS, *Carouge, near Geneva, Switzerland*, and JULES LERESCHE-GOLAY & Co., *Vaulion, Ct. Vaud, Switzerland*, had each an exhibit of the same class of tools; that by Vautier & Sons was of superior excellence. Indeed, the cutting of the finer description of the smaller size from Switzerland, and also France and Belgium, showed a delicacy of touch not often seen, and the inspection of their tools produced real pleasure.

SCREW-CUTTING.—The number of screwing-machines now in use, and the increase of bolt and nut manufacturers exclusively engaged in the trade, render the use of the ordinary screw plate or die stocks less necessary than it was formerly. In the Exhibition there were only a few exhibits where screwing-tools were represented.

An excellent exhibit was shown by the MORSE TWIST DRILL AND MACHINE COMPANY, *New Bedford, Massachusetts*. We had here a selection of tools of a high character. The taps and dies are made from specially-imported steel, and are supplied to either of the American standards or to the Whitworth as required. The screw plates are made of a slight character, and the manner in which the die is fixed admits of its being quickly changed. The exhibitors also manufacture a tool for screwing pipes up to three inches in diameter; the die in this case is solid, and is fitted into a box with two handles. In addition the exhibit contained twist drills, chucks, and wrenches of superior quality.

J. M. CARPENTER, *Pawtucket, Rhode Island*, also showed a good selection of stocks with taps and dies. The stocks are constructed on an excellent principle for fixing and changing the dies. The taps and dies are made of special steel to any gauge in sets of three taps to one pair of dies. The stocks are well proportioned.

AGRICULTURAL AND LABORERS' TOOLS.—There were several exhibits connected with agriculture and other kinds of labor which were brought under the consideration of Group XV.

Looking at the exhibits shown in this class at Philadelphia, we are surprised that the great improvements which have been made in the United States in agricultural tools had not been introduced many years ago. The spade was made formerly by having two layers of iron, and a thinner plate of hoop L or of shear steel placed between them by the usual process of welding. The spade was made solid, then cut to the required size, and the scales at the top formed for the handle.

The old hay-fork was made altogether of iron, or occasionally the prongs were pointed with steel. With its iron ferrule and strong ash handle, it was a very cumbrous tool. The manure-fork had usually three prongs, sometimes flat, about an inch broad, and was occasionally improved by forming the prongs in the shape of the letter V. If the hay-fork was cumbrous the manure-fork was doubly so. No accurate judgment can be formed of the many advantages which have been conferred on the laborer by the introduction of the American steel spade, shovel, manure- and hay-forks, arising from the surface of the metal remaining clean, and the edges or points sharp, while, as it was stated in the Exhibition, the difference of weight between the old style and the new steel spade was from 3 to 4 pounds in favor of steel.

The exhibition of the A. S. WHITTING MANUFACTURING COMPANY, *Ottawa, Ontario*, contained a varied collection of steel hay- and manure-forks, hoes, and garden tools, of excellent quality and workmanship, and extremely light. As is well known, this quality of goods has for years been imported into Great Britain, being preferred to the older form on account of lightness, and for the freedom with which they can be worked for a much longer time than the heavy forks of former years.

The AMERICAN SHOVEL COMPANY, *Birmingham, Connecticut*, exhibited several specimens of steel shovels and scoops; the shovels are of sufficient thickness, and well fastened to properly-shaped handles. The shovel is polished, is comparatively light, and of good workmanship. The scoops are well made, and very suitable for the intended purpose.

The MIDDLEBORO' SHOVEL COMPANY, *Boston, Massachusetts*, also showed a variety of steel shovels and spades, made up in the usual manner, with good ash handles; the implements are polished and well suited for work.

B. ROWLAND & Co., *Philadelphia, Pennsylvania*, exhibited an exten-

sive assortment of shovels, spades, and scoops, draining and ditching tools; the manufacture of the implements comprised in this exhibit was marked by careful attention to the best construction of the different tools, and to the lightness of the implement consistent with the necessary strength and fitness for the purpose. The exhibit was very commendable for design and workmanship.

CLASS 281.—CUTLERY.

In this class several of the exhibits contained only one section of the class, while others presented several varieties. In this report the remarks must be limited to those exhibits which best represent the present state of the art in the different nationalities, the purpose being to present a mere general sketch of the grand display exhibited at Philadelphia, and convey an impartial idea of the progress of this particular branch of industry.

Cutlery has been the most important product of the Sheffield district for centuries, and in our day Sheffield still maintains a prominent position in the department of steel manufacture. Still, the number and excellence of several of the exhibits at Philadelphia show clearly that there exists an active emulation among the manufacturers of cutlery in several of the countries in Europe, but especially in America, where during recent years great improvements have been made in the manufacture, both in the taste and in the quality of the goods, which is very remarkable. The quality of fine cutlery depends mainly on the character of the steel, upon the workman's skill, and on the taste shown in the finish of the handle, though the last may be considered as secondary to the others. The mode of joining the handle to the blade is also an important point. It may be assumed that for the finest branches of cutlery the best quality of cast-steel of Sheffield manufacture is generally adopted. This has been stated by some of the exhibitors of fine-class goods, in answer to inquiries regarding the character of the steel used in the manufacture, and is a fact of vast importance not only to Sheffield but to England.

UNITED STATES.

The most extensive exhibit of this class was the property of the JOHN RUSSELL CUTLERY COMPANY, *Green River Works, New York, N. Y.*, and comprised every variety of table cutlery, mounted with handles of pearl, silver, plated handles, ivory, horn, and fancy woods. The carving-forks had an improved guard of a double form; the guard on the upper side was made in the usual manner, but the lower half

of the guard was formed with double points, resembling a short fork, slightly turned up, and forming a rest for the fork when not in use, and admitting of being forced back when laid aside. A grander display than this exhibit, especially of the finer sections, has rarely been witnessed. The varieties of style, the uniform excellence of the manufacture, as shown by the specimens, were deserving of the highest praise.

The MILLER BROTHERS CUTLERY COMPANY, *West Meriden, Connecticut*, exhibited an extensive assortment of pocket-cutlery in all the different varieties and qualities. An interesting part of this exhibit consisted in showing specimens of their goods in the consecutive stages of the manufacture, namely, the forged blade, the progress of finishing, tempering, grinding, and polishing, the preparation of the handle, and final finish. The examples contained in this exhibit were of tasteful designs and excellent workmanship.

R. HEINISCH'S SONS, *Newark, New Jersey*, exhibited a varied selection of tailors' and other descriptions of shears and scissors. The specialty of this exhibit consisted in the manufacture of tailors' shears, which had a peculiarly-formed handle, made by Mr. Heinsch's Sons out of cast malleable iron, to which in the process the cast-steel face is attached. The manufacture was skillfully executed; it was difficult to see (when the shears were polished) where the union of the two metals had taken place. It was stated that many of this description were exported to Great Britain. The whole of this exhibit indicated careful workmanship, and was very creditable.

A well-selected variety of razors was exhibited by FRIEDMAN & LAUTERJING, *New York, N. Y.* These were described as "concaved razors manufactured out of India steel." The "India steel" may be assumed to mean that a slight alloy of silver has been added to the cast-steel in the process of manufacture. Most razors have a degree of concavity more or less; this exhibit, however, showed, upon examination, to have the concave carried almost up to the back of the razor, and in this manner the edge appears extremely fine. The workmanship of the blades and of the ivory mountings was of excellent quality. This firm also exhibited a variety of razor-strops made of strong Russian leather; the strop was fitted on to a slight frame of wires about $\frac{3}{4}$ inch apart and 8 inches long, and the frame was connected to the handle by an adjusting-screw by which the strop could be tightened as required; the strops were very neatly made.

The MERIDEN CUTLERY COMPANY, *Meriden, Connecticut*, exhibited a choice selection of table-cutlery in all its varieties. They claim a specialty in the material of which the handles are formed; it bears a

close resemblance to ivory, and takes on a fine polish ; it was stated to be a third cheaper than the ivory handle. The best qualities of the exhibit were of superior workmanship.

GREAT BRITAIN.

GEORGE WOSTENHOLM & SON, *Sheffield, England*, exhibited a well-arranged assortment of razors, pocket-knives, scissors, and general cutlery ; the examples were tastefully designed, and executed in a superior style. It was the unanimous decision of the Judges that the exhibit of George Wostenholm & Son, in point of tasteful design, quality, and style of finish, was not surpassed by any exhibit in the same class at the Centennial Exhibition.

A large display of cutlery by BROOKS & CROOKES, *Sheffield, England*, comprised a varied selection of table- and pocket-knives, scissors, and toilet-furnishings ; also, hunting-knives, dirks, etc. This firm manufacture their own steel. The exhibit showed considerable taste in the unexceptionable quality of the goods.

The exhibit of THOMAS KINGSBURY, *London, England*, contained a varied assortment of razors, knives, scissors, dressing-case instruments, and several specimens of processes of manufacture. The variety of specimens in different classes were of good design and of excellent quality ; the specimens in progress were in the usual form.

WILLIAM WILKINSON & SONS, *Sheffield, England*, exhibited a different class of cutlery from any of the other Sheffield firms, viz., a selection of pruning-shears and farriers' knives. The value of this class of tools consists in the quality of the steel, and in the skill of the workman in their construction ; a high finish is not required. This exhibit evinced great care, and the tools were admirably adapted for the purposes intended.

FRANCE.

A very large case, divided into several compartments, contained the exhibits of individuals from *Haute Marne*, viz., RENAUT GUILLEMIN, CHARLES GIRARD, COURCELLES SOMMELET, FELIX THÉVENOT, J. CHARBONNE-THUILLIER, WICHARD COUVREAU ; also, VITRY FRÈRES and THINET, from *Paris*. The separate exhibits thus combined almost uniformly, to a greater or less degree, contained the same description and quality of examples, viz., hunting- and pocket-knives, kitchen- and mincing-knives, daggers, razors, folding and common scissors, and a variety of corkscrews and pruning-shears. In this very extensive exhibit there did not appear to be any specialty (with one exception to be noted) to require any particular remark. A uniform

creditable type of workmanship was well maintained by every exhibitor, and where a better style of finish was required the work (with few exceptions) was executed with skill. It is easy to see that this combined form of exhibit may be very economical, but it is equally clear that it has its disadvantages, in the difficulty with which an examination of the articles can be made.

The exception above noted has reference to the exhibit of Courcelles Sommelet, which contained a selection of shears and scissors, kitchen-knives, etc., the product of the labor of juvenile offenders, the inmates of a reformatory institution, and in the circumstance not without merit. It was understood that the whole of the work was done within the walls of the institution.

A new form of sheep-shears was exhibited by V. PÉRARD, *Paris*. They are constructed on much the same principle as the clipping-shears now generally used for horses. In inexperienced hands, their employment would greatly diminish the risk of cutting the skin, and the new form is on that account a great improvement on the ordinary shears for clipping wool.

AUSTRIA.

The only exhibit in this class was by WENZEL SCHNEIDER, *Prague*, consisting of a selection of pocket-cutlery of excellent quality and of beautiful finish.

SWEDEN.

F. W. SODERÉN, *Eskilstuna*, exhibited a selection of shears and scissors of great merit; the examples shown were of superior quality and meritorious.

The exhibit of THE SANOVIKENS IRON & STEEL COMPANY, *Gefle*, contained a number of razors, knives, and scissors. The whole of the examples were said to be manufactured out of Bessemer steel made by the company. From the workmanship and finish shown on the goods the specialty of the steel would appear to be of a superior kind. It opens a new (though probably not the most suitable) use for this cheap quality of steel.

There was a fine exhibit of razors from C. V. HELJESTRAND, *Eskilstuna*. The blades were of the finest steel; the handles were mostly of ivory, tastefully engraved. The examples shown were executed in a most superior manner.

C. ALFRED MORSTROM, *Eskilstuna*, exhibited a selection of hunting-knives of best quality of steel, mounted with tastefully-carved handles, with silver hoops and ornaments,—altogether a fine display of superior workmanship.

GERMANY.

H. BOKER & Co., *Solingen*, exhibited a very fine display of pocket-knives, scissors, etc. The examples were doubtless made up for exhibition. The pocket-knives and scissors were from the finest steel, and were remarkable for the high class of the workmanship. There was also supplied, at request, a selection of the ordinary manufacture, of good quality and at moderate prices. Altogether this exhibit was considered to be of a very superior kind, and showed the amount of careful attention that had been bestowed upon it.

RUSSIA.

A very extensive selection of table- and pocket-cutlery, pruning-knives, and shears, was exhibited by JOHN KALIAKIN & SONS, *Pavlovo, Government of Nijni Novgorod*. The table-cutlery comprised a variety of the usual requirements included in that class; the taste shown in the variety of the handles was excellent. The pocket-knives were beautiful in style, and indicated skillful workmanship. The pruning-knives and shears were of good quality and carefully made. Altogether this selection was very commendable.

The exhibits from DEMETRIUS KONDRATOFF, *Vatcha, Government of Vladimir*, and ALEXIS ZAVIALOFF, *Vorsma, Government of Nijni Novgorod*, comprised the same examples of table- and pocket-cutlery; the specimens were of good quality, and the taste shown in the workmanship very creditable. The pruning-knives and shears from Novgorod showed skillful workmanship, which in both exhibits was very superior.

SWITZERLAND.

C. F. SCHNEIDER, *Geneva*, exhibited an assortment of knives both with single and multifarious blades; both descriptions showed very great taste in the arrangement and in the fine quality of workmanship, for which the Swiss for long years have been justly distinguished. The beautiful arrangement of the many-bladed knife was very attractive.

JACQUES LE COULTRE, *Sentier, Ct. Vaud*, exhibited a collection of razors of different patterns. The specialty of the exhibit consisted in having cases containing a number of razors with one handle, by which a different razor could be used each day; the examples were made of the finest steel, and beautifully ground and polished. The blades were formed with a short tang which fitted into a steel socket of the same form as the end of an ordinary razor.

After a general survey of the cutlery exhibition, we are forced to give to America the first place for table-cutlery.

For pocket- and fine cutlery the pre-eminence of Sheffield was maintained by Westenholm and Brooks & Crookes. France did scarcely justice to herself in the exhibits sent to Philadelphia.

The display of Germany in pocket-cutlery was no doubt equal to any from the United States, showing great beauty and high excellence of finish.

The Russian exhibits from Novgorod showed an advance which we were scarcely prepared to see; and Sweden also deserves to be noticed, her products being somewhat of the same quality as those of Russia.

SKATES.—The FLORENCE SEWING-MACHINE COMPANY, *Florence, Massachusetts*, showed an assortment of ice-skates; the specialty consisted in the mode by which the skate was attached to the foot. A strap passes around the ball of the foot, and from heel over instep, and the skate is secured to the boot by a thumb-screw at the back of the heel. It was understood that a patent had been obtained for this mode of fixing.

The STAR MANUFACTURING COMPANY, *Halifax, Nova Scotia*, exhibited, with their general collection, a beautiful stand of the "Acme Patent Club-Skate." The skates were shown in great variety, of elegant style, and of superior finish. The exhibit obtained an award of merit.

A different variety of skate was exhibited by the PLIMPTON ROLLER-AND ICE-SKATE COMPANY. The exhibits were of the ordinary type. There was no specialty pointed out, though the style and workmanship were of very good quality.

CLASS 282.—POLISHING AND BURNISHING MATERIALS.

There is little to be said on this class, although the importance of the materials included under it is beyond dispute. To take emery: the part which it is now playing in cutting-wheels and in wheels for surfacing in machinery is producing many changes in the modes of production; but here we have only to deal with it as a material for polishing. In the class there were two main divisions, viz., burnishers and materials for polishing.

GEORGE LEYKAUF, *Nuremberg, Bavaria*, exhibited a fine collection of burnishing-tools for use in gilding. These burnishers were made of chalcedony and jasper. These stones, which are found in abundance in Eastern Europe, had their points formed in every variety of

shape, so that they might be applied to every part of an ornamental carving. They were very highly polished, and fixed on wooden handles. This was a beautiful exhibit.

JAMES TAYLOR, *Providence, Rhode Island*, made a display similar to that just described. These burnishers were adapted for use on carved wood and picture-frames, or such like articles of furniture.

As is well known, the burnishers used for metals are very different from those used for gilding, being composed of fine steel blades with a perfectly smooth edge, the form being governed by the manner in which the burnisher is to be employed. The preparation of the surfaces to be burnished is effected either by the file or by the process of grinding. The ordinary grindstone, in some cases, may be sufficient in the first instance, but the emery-stone is found more expeditious. It is used with water or dry, and is driven at a high speed. To perfect the surface, emery-wheels of different grades of fineness are used in their turn. Crocus buffs are next employed, and ultimately putty-powder, which is found sufficiently fine to produce a finished surface.

The most important of the grinding-materials is emery, a mineral of the hardest quality, and universally used in the manufacturing departments of art in grinding and polishing plate-glass, lenses, precious stones, granite, and in engine- and machine-shops. Emery is found in the east of Europe in lumps of considerable size, and sufficient, in some cases, to form wheels for grinding from 15 to 18 inches diameter and $2\frac{1}{2}$ inches thick. The emery-stone is often carefully fixed upon an iron spindle, and in this form is extensively used either dry or with water. The smaller pieces are broken down into fragments, and are ground to any required grade in the rolling-mill. Sometimes the separation of the different grades is effected by an elaborate process of washing, but in some of the recently-erected manufactories in England the rolling-mill, with its variety of sifters, has been found more economical in point of time and labor. It is stated that the finest grade of flour-emery has been found to be the dust falling from the grinding and sifting processes, which is carefully removed from prepared receptacles formed so as to prevent the chance of any foreign matter being mixed up with it. The coarser varieties are numbered by consecutive figures thus: 0, $0\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3; in some cases the qualities are marked by the number of meshes contained within a square inch; this mode is much more likely to be satisfactory than consecutive numbers. This material is also manufactured into emery-cloth and paper by first coating the paper with prepared glue and sifting the emery evenly on the sur-

face; the cloth is generally of coarse calico, and is treated in the same manner as the paper. Flour-emery-cloth requires a finer cloth; the process of sifting is the same. When skillfully prepared the emery-cloth is preferable to the paper; it endures greater fatigue, is not so liable to tear, and can be used for a longer time. Emery is also used for scythe-sharpeners by forming a piece of wood into the shape of a flat file with handle, and about 2 inches broad, 12 inches long, coating it with glue, and dipping the wood once or twice in a heap of emery. Emery is also applied to buffing-wheels by mixing it with beeswax and melted fat well worked together.

Crocus is applied in the same way. Crocus is the finely-divided red oxide of iron, and is carefully prepared and reduced to a fine powder, free from grit; the cloth is covered with this powder in much the same form as in the process of covering cloth with flour-emery.

The examples of these various articles shown were subjected to a severe test without any appearance of weakness, and the emery never showed any parting from the cloth in the slightest degree. In the exhibit of FREEMAN K. SIBLEY, *Waltham, Massachusetts*, especially, the surfaces were beautifully regular, and the whole worthy of commendation.

CLASS 283.—METAL HOLLOW WARE AND ORNAMENTAL CASTINGS.

This class comprises a number of objects which, from their beauty, attracted a large number of admiring spectators.

There is hardly a civilized country where the bronzes of antiquities of Greece and Rome—nay, even of China and Japan—are not admired and imitated. To France must be given the highest place as the mistress of artistic bronze in modern times; but we are reminded by this Exhibition that a large group of artistic metal productions have sprung up in various countries, though all to a greater or less degree in sympathy with the character of the French bronzes. Among these we notice the zinc- and iron-castings of Germany and the United States.

The ornamental use of zinc is of very modern date. Indeed, it owes its origin to the desire which the general spread of refinement has produced, of having about us in our homes articles in which pure artistic feeling is present. To the rich this was always within reach, but to the poorer classes the possession of a good bronze was a thing not to be thought of. The comparative cheapness of zinc figures, more especially when cast by the hundred from a perfect metal mould, has brought the possession of beautiful objects within the reach of persons with slender incomes, and a large trade has

thereby been created. The principal necessity for perfection lies in the preparation of the moulds, which, whether of sand or of metal, must be without fault and equal in finish to a piece of sculpture. The same remarks apply to the iron-castings which have found homes in Germany and the United States, where they are produced in great variety and perfection. The sharpness of many of these castings is wonderful, and convinces one of the need, first, of a perfect mould, and, secondly, of a very fluid metal.

In the Exhibition by far the largest and most important display was that of the J. L. MOTT IRON-WORKS, *New York, N. Y.* The extreme elegance of the iron figures was sufficient index of the artistic feeling of the modeler, while the delicacy with which the various bronzes were applied to the surface showed that the American workmen were in no respect inferior to those of Europe. A large fountain in the centre circle of the Main Building was throughout of the highest character, and extracted praise from every one who inspected it.

Another exhibit of zinc-castings was shown by CONRAD FELSING, *Berlin, Prussia*, containing a collection of bust statuettes. The castings were remarkably sharp and clean, and tastefully imitated in bronze color; this exhibit possessed great merit.

ALOIS WINKLER, *Vienna, Austria*, exhibited a series of zinc figures and letters, in different styles, executed in a very skillful manner, and of beautiful designs.

GRAF STOLBERG, *Ilsenburg, Germany*, exhibited several iron-castings of great merit. Two castings of engraved shields were particularly noticeable; they were about 20 inches diameter, and cast in sand. They were extremely light, the pattern had been richly engraved, and the casts were both smooth and sharp; nothing had been done to improve them by filing; one of the castings had not had the sand brushed off. The exhibit was greatly commended.

A novelty in casting which we had not previously seen consisted of an exhibition of sash-weights; some were broken in pieces to show the quality of the metal; the Judges were informed by the exhibitor, J. H. ARMBRUSTER, *Philadelphia, Pennsylvania*, that he employed laborers with carts to collect during the morning every article of worn-out tin plate or sheet-iron, in whatever shape, used for domestic purposes that had been thrown out upon the street. The weight of the rubbish gathered in this manner was surprising, as was also the product from the furnace. At present it is made into sash-weights of a much higher specific gravity than ordinary iron. The metal also shows a degree of hardness equal to spiegeleisen or franklinite, and resists any attempt to operate upon it with the hardest steel. It is

quite within the range of possibility that this product may yet be applied to more important purposes than sash-weights. The industry of the exhibitor was highly commended.

CLASS 284.

A very great variety exists in the different articles grouped under the head of Class 284. The remarks are confined to the following sub-classes, viz., bolts and nuts, screws and nails, horse-shoes, bells, anvils, etc.

BOLTS, SCREWS.—There was a particularly good representation of these articles, some of the cases containing thousands of specimens. Probably the point which most attracted attention was the surprising manner in which cold punching had been applied in the manufacture of nuts. Specimens cold-punched were shown with a hole of $\frac{1}{2}$ inch diameter through a nut of nearly 2 inches depth. The cleanness of the perforation was perfect, and showed that the doctrine of the flow of solids, so well expounded by M. Tresca, is beginning to bear fruit. The material of the punches used must have been excellent, and time for the material of the nut to move must have been fully allowed.

The extensive exhibit of HOOPES & TOWNSEND, *Philadelphia, Pennsylvania*, contained almost every size and form of bolt and nut, car-forgings, cold-punched nuts, all manufactured from the best brands of refined iron, and with the best workmanship.

There was included a collection of elevator- and carrier-chains with punched links. In the manufacture of such chains it is necessary to see that equal strength is given throughout the various parts of the link, and it will be well for those interested to study the account of the recent experiments which have been made with the view of determining very exactly the strength to be given at the eyes of the links.

The PATENT BOLT & NUT COMPANY, *Birmingham, England*, exhibited an immense number of bolts, spikes, rivets, clench-rings, etc. Some of the specimens were sawn through the centre longitudinally to show the fitting of the bolt and nut; this was a fine display.

MESSRS. PIERRE & NICOLAS NICAISE, *Marcinelle, near Charleroi, Belgium*, showed bolts and nuts, as well as forged rivets and clamps, for railway purposes. These articles were well made, and the material was of high quality.

SCREWS AND NAILS.—The AMERICAN SCREW COMPANY, *Providence, Rhode Island*, presented a very extensive collection of steel, iron, and brass screws for every purpose, from $\frac{1}{4}$ inch to 5 inches in length. The importance of this display may be estimated from the fact that 3000 varieties were exhibited, all manufactured from excellent mate-

rial and in every respect meritorious. The gimlet-pointed screws particularly attracted notice for the efficiency of their design for penetration, and the steel screws were especially good.

PILLOW, HERSEY, & CO., *Montreal, Canada*, exhibited brads, spikes, and nails in endless variety and kind suitable for general use. The fine quality of the iron and the workmanship were highly commended.

France sent a beautiful display of decorators' nails and ornaments, manufactured in brass, steel, and bronze. The exhibitor was CELESTIN CARMOY, *Paris*. The numberless varieties submitted were very tastefully designed and beautifully executed. The French nation seem to have had, and even now to maintain, a superior power in the artistic design and production of such articles as are above referred to.

HORSE-SHOES.—Probably nothing was better represented than the manufacture of horse-shoes. The world has come to see that there is much to be done in improving the horse-shoe, at least very much beyond the point reached twenty or thirty years ago. The increased value of horses and the more refined ideas of what our treatment of animals should be have together resulted in much attention being paid to shoeing. While in England Mr. Fleming has probably led the way to improvement, in America many minds have been studying the subject. It is thus that we found at Philadelphia a grander collection of horse-shoes, both as regards finish and variety, than had at any previous time been presented to the world. To bear this out it may be stated that one American firm produces weekly 600 tons of shoes, and another from 200 to 250 tons.

MESSRS. H. BURDEN & SONS, *Troy, New York*, exhibited a large number of horse- and mule-shoes. They were machine-made, the insides of the shoes very properly hollowed out with correct form. Some specimens were tested for quality, and the material found to be the best Port Henry iron. This was a very superior exhibit.

The RHODE ISLAND HORSE-SHOE COMPANY, *Providence, Rhode Island*, sent a collection of machine-made shoes of selected scrap. They were particularly noticed on account of their smoothness and excellent finish.

S. S. PUTNAM & CO., *Neponset, Massachusetts*, showed hammer-pointed horse-shoe nails, very clean, and made of a superior quality of iron.

The NATIONAL HORSE-NAIL COMPANY, *Vergennes, Vermont*, displayed different varieties of machine-made horse-shoe nails, both plain and polished. They were uniformly well made, and found to be of excellent quality.

AARON W. SMITH, *Manchester, New Hampshire*, exhibited a flexible horse-shoe for the relief and cure of contracted or flat feet. The shoe is formed with a joint at the toe. From the number of certificates of cures effected by the use of these shoes it was apparent that they are very efficient. The style in which the shoes were made was very creditable.

MESSRS. HOTCHKISS' SONS, *Bridgeport, Connecticut*, claim to have the largest and most complete selection of curry-combs. Their exhibit undoubtedly showed great numbers and varieties, with open and closed backs, plain and ornamental, with from 5 to 8 bars, and several with the mane- and curry-comb combined. This display evinced great care and study in the production of the articles.

BELLS.—The GONG-BELL MANUFACTURING COMPANY, *East Hampton, Connecticut*, exhibited a case of polished bells for hand-, call-, and sleigh-bells; also a stand of gongs, of which several were mounted. The examples were beautifully finished, and excellent in tone and quality.

The BEVIN BROTHERS MANUFACTURING COMPANY, *East Hampton, Connecticut*, exhibited a large assortment of the same class of goods of very creditable workmanship.

VANDUZEN & TIFT, *Cincinnati, Ohio*, exhibited several examples of bells for churches, and gongs of clear tone and of good workmanship.

ANVILS.—MESSRS. FISHER & NORRIS, *Trenton, New Jersey*, exhibited anvils of a rather novel construction, being cast-iron for the body and faced with steel. The process of the manufacture of these articles is essentially American. The difficulty of welding large masses of wrought-iron to the steel face (which has been generally the plan followed) has been got over by the introduction of cast-iron. The examples shown were of considerable weight. The steel face was sound, and appeared to be completely united to the iron. On the polished surface there was no appearance of crack or flaw. The exhibit was highly commended.

An immense number of manufactured goods were shown by the BENEDICT & BURNHAM MANUFACTURING COMPANY, *Waterbury, Connecticut*. This exhibit is mentioned in order to refer to the great excellence of the rolled sheets of brass, copper, and German silver. These plates were of large size, and the surfaces were so fine and perfect that they acted as reflectors. This company also had some specimens of chain which were much admired for their clean manufacture.

REPORTS ON AWARDS.

GROUP XV.

1. Henry Disston & Sons, Philadelphia, Pa., U. S.

SAWS, TROWELS, PLUMBS AND LEVELS, SQUARES, HINGES, AND TURNSCREWS.

Report.—A very large display, of surpassing excellence of material, style, and finish; every article worthy of the highest commendation.

2. Nicholson File Co., Providence, R. I., U. S.

FILES AND RASPS.

Report.—Commended as exceedingly well cut and of excellent material.

3. Freeman K. Sibley, Waltham, Mass., U. S.

EMERY AND CROCUS CLOTH.

Report.—Commended as of excellent quality and highly meritorious.

4. Benjamin Forstner, Salem, Oregon, U. S.

PATENT PERPETUAL LIP AUGER-BITS.

Report.—Commended as an ingenious and most useful tool.

5. Enterprise Manufacturing Co., Philadelphia, Pa., U. S.

SAD-IRONS, COFFEE-MILLS, AND TOBACCO CUTTERS.

Report.—Commended as a large assortment of useful articles and of improved styles.

6. Eben Moody Boynton, New York, N. Y., U. S.

SAWS IN GREAT VARIETY; SPECIAL IMPROVEMENT IN SHAPE OF TEETH CALLED "PATENT LIGHTNING SAWS."

Report.—Commended as of very superior quality and of great practical utility.

7. Baeder, Adamson, & Co., Philadelphia, Pa., U. S.

SANDPAPER, EMERY PAPER, AND EMERY CLOTH.

Report.—Commended as handsomely made and of excellent quality of material and manufacture.

8. Stephens Patent Vise Co., New York, N. Y., U. S.

PARALLEL VISES AND PLANER CHUCKS.

Report.—Commended as useful tools of ingenious construction.

9. Western File Works, Beaver Falls, Pa., U. S.

FILES AND RASPS.

Report.—Commended as well-cut and handsome goods.

10. Fisher & Norris, Eagle Anvil Works, Trenton, N. J., U. S.

ANVILS AND VISES.

Report.—The anvils are commended as being of excellent quality.

11. McCaffrey & Brother, Philadelphia, Pa., U. S.

HAND-CUT FILES AND RASPS.

Report.—Commended for a large variety of superior goods.

12. G. & H. Barnett, Black Diamond Works, Philadelphia, Pa., U. S.

HAND-CUT FILES AND RASPS.

Report.—Commended as very superior goods.

13. The Douglass Manufacturing Co., Seymour, Conn., U. S.

CHISELS, AUGERS, AUGER-BITS, AND DRAW-KNIVES.

Report.—Commended as very fine goods, highly finished, and of superior workmanship.

14. A. G. Coes & Co., Worcester, Mass., U. S.

SCREW WRENCHES.

Report.—Commended as first-class goods and low in price.

15. American Saw Co., Trenton, N. J., U. S.

MILL AND CROSS-CUT SAWS.

Report.—Commended as well finished and well adapted for use.

16. Edward H. Knight, Philadelphia, Pa., U. S.

PATENT WRENCH (ADJUSTABLE).

Report.—Commended as a very useful and labor-saving invention.

17. J. M. Carpenter, Pawtucket, R. I., U. S.

STOCKS WITH TAPS AND DIES.

Report.—Commended as extremely well finished.

18. Quaker City Stencil Works, Philadelphia, Pa., U. S.

CAST LETTERS, SIGNS, AND BADGES.

Report.—Commended as very neat designs and well executed.

19. S. H. Quint & Son, Philadelphia, Pa., U. S.

STENCILS AND PATTERN LETTERS.

Report.—A great variety of excellently well-made articles.

20. Clough & Williamson, Newark, N. J., U. S.

WIRE CORKSCREWS.

Report.—Commended as strong, durable, well-made, and cheap goods.

21. Limet-Lapareillé & Co., Paris, France.

FILES AND RASPS.

Report.—Commended as of excellent quality and well adapted for intended purpose.

22. A. de Lambert, Liège, Belgium.

WATCHMAKERS' AND JEWELERS' TOOLS.

Report.—Commended as showing great precision of workmanship, especially in file-cutting.

23. W. F. Palmer, San Francisco, Cal., U. S.

SHIP-CARPENTERS', HOUSE-CARPENTERS', COOPERS', AND BUTCHERS' EDGE TOOLS.

Report.—Commended as good serviceable tools and substantially made.

24. George Leykauf, Nuremberg, Germany.

BURNISHING STONES.

Report.—Commended as of high quality and finish.

25. R. & H. Vorster, Hagen, Germany.

EDGE TOOLS.

Report.—Commended as of good design, finish, and quality, and moderate in price.

26. Wilhelm Eisenführ, Berlin, Germany.

STOCKS, DIES, AND REAMERS.

Report.—Commended as good serviceable tools made by hand.

27. J. Marc Servet, Son, Geneva, Switzerland.

TOOLS AND INSTRUMENTS FOR WATCHMAKERS.

Report.—Commended as very creditable in workmanship, especially in correctness of the file-cutting.

28. Sl. Vautier & Sons, Carouge, near Geneva, Switzerland.

WATCHMAKERS' AND JEWELERS' TOOLS.

Report.—Commended as of good quality and finish; files cut with great precision and beauty.

29. Dates Patent Steel Co., Toronto, Ontario, Canada.

AXES AND EDGE TOOLS.

Report.—Commended as of excellent quality and styles.

30. Middletown Tool Co., Middletown, Conn., U. S.

PLANE IRONS.

Report.—Commended as of good quality and highly finished.**31. Bailey Tool Co., New York, N. Y., U. S.**

IRON PLANERS AND SPOKESHAVES.

Report.—Commended as well-made and well-finished goods.**32. Josiah King & Son, New York, N. Y., U. S.**

PLANES OF ALL VARIETIES.

Report.—Commended as of general good quality.**33. William Rose & Brothers, Philadelphia, Pa., U. S.**

BRICK, PLASTERING, AND MOULDERS' TROWELS.

Report.—Commended as first-class in every respect.**34. William Johnson, Newark, N. J., U. S.**

CARPENTERS' AND OTHER MECHANICS' TOOLS AND OTHER HARDWARE.

Report.—Commended as very serviceable tools.**35. Carr, Crawley, & Devlin, Philadelphia, Pa., U. S.**

BUILDING AND CABINET HARDWARE; ALSO BRASS AND MALLEABLE CASTINGS.

Report.—Commended as excellent and useful goods.**36. Ohio Tool Co., Columbus, Ohio, U. S.**

PLANES, BENCH-SCREWS, CHISELS, DRAW-KNIVES, AND PLANE-IRONS.

Report.—Commended as of good quality and well made.**37. D. Maydole & Co., Norwich, N. Y., U. S.**

HAMMERS OF ALL SIZES AND FOR ALL PURPOSES.

Report.—Commended as first-class in every respect.**38. The Collins Co., Hartford, Conn., U. S.**

AXES, HATCHETS, PICKS, ADZES, WRENCHES, AND CANE-KNIVES (MACHETES).

Report.—Commended as of best quality and finish.**39. Yerkes & Plumb, Philadelphia, Pa., U. S.**

HAND-AXES, HATCHETS, CLEAVERS, AND HAMMERS.

Report.—Commended as of superior quality.**40. Klein, Logan, & Co., Pittsburg, Pa., U. S.**

PICKS, MATTOCKS, STONE-HAMMERS, AND SLEDGES.

Report.—Commended as well-made goods.

41. A. W. Crossman & Son, West Warren, Mass., U. S.

CHISELS AND DRAW-KNIVES.

Report.—Commended as highly finished ; also thoroughly well made.

42. The Douglas Axe Manufacturing Co., East Douglass, Mass., U. S.

AXES, HATCHETS, PICKS, AND ADZES.

Report.—Commended as being all first-class goods.

43. Henry Seymour & Co., New York, N. Y., U. S.

MALLEABLE SHEARS AND SCISSORS (STEEL LINED).

Report.—Commended as of good quality ; also well finished.

44. Alfred J. Colton, Philadelphia, Pa., U. S.

PLANES.

Report.—Commended as of excellent quality and superior workmanship.

45. United States Steel Shear Co., West Meriden, Conn., U. S.

FORGED CAST-STEEL SHEARS AND SCISSORS.

Report.—Commended as excellent goods.

46. Leonard Bailey & Co., Hartford, Conn., U. S.

IRON PLANES, TRY-SQUARES, AND BEVELS.

Report.—Commended as of excellent quality and finish.

47. George Selsor & Co., Philadelphia, Pa., U. S.

HAMMERS, HATCHETS, HAND-AXES, AND BOX COFFEE-MILLS.

Report.—Commended as of uniform good quality ; also finely finished.

48. Harrison & Kellogg, Troy, N. Y., U. S.

CASTINGS OF MALLEABLE IRON AND SCREW WRENCHES.

Report.—Commended as very smooth and of excellent quality.

49. W. C. Allison & Co., Philadelphia, Pa., U. S.

PATENT COUPLING FOR IRON PIPES, ESPECIALLY FOR OIL WELLS.

Report.—Commended as having a vanishing screw, which permits a bearing at all points without weakening the tube.

50. Job T. Pugh, Philadelphia, Pa., U. S.

AUGERS, BITS, AND FLOUR-TRIERS.

Report.—Commended as of very superior quality in every respect.

51. Alexander Krumbhaar, Philadelphia, Pa., U. S.

HAND-CUT FILES AND RASPS.

Report.—Commended as well cut and of excellent quality.

52. Sandusky Tool Co., Sandusky, Ohio, U. S.

CARPENTERS', JOINERS', AND WOOD-TURNERS' TOOLS.

Report.—Commended as of the very highest quality and finish.

53. De Witt, Morison, & Kelley, Philadelphia, Pa., U. S.

AUGERS, AUGER-BITS, AND FLOUR-TRIERS.

Report.—Commended as first-quality in all respects.

54. The D. K. Miller Lock Co., Philadelphia, Pa., U. S.

SELF-LOCKING PADLOCKS.

Report.—Commended as very fine in every particular.

55. The Davis Level and Tool Co., Springfield, Mass., U. S.

LEVELS AND PLUMBS.

Report.—Commended as of superior quality and finish.

56. Snell Manufacturing Co., Fiskdale, Mass., U. S.

AUGERS, AUGER-BITS, AND BORING-MACHINES.

Report.—Commended as of very superior quality and finish.

57. The Langdon Mitre Box Co., Miller's Falls, Mass., U. S.

MITRE-BOXES WITH FIXED SAWS.

Report.—Commended as exceedingly well-made and useful tools, and adjustable to any angle.

58. Hart, Bliven, and Mead Manufacturing Co., Kensington, Conn., and New York, N. Y., U. S.

BUILDING AND HOUSEHOLD HARDWARE, FURNITURE TRIMMINGS, AND CARPENTERS' TOOLS

Report.—Commended for the great range of varieties and excellent quality and finish.

59. Peter Robertson, Ottawa, Ontario, Canada.

LUMBERMEN'S AND STONECUTTERS' TOOLS.

Report.—Commended as of good quality and serviceable tools.

60. Thomas Moore, Cooksville, Ontario, Canada.

AXE AND TOOL HANDLES.

Report.—Commended as of excellent material and well made.

61. R. H. Smith & Co., St. Catharines, Ontario, Canada.

SAWS.

Report.—Commended for the good quality and finish of their exhibit of mill, cross-cut, circular, and other heavy saws; also for their hand-saws, buck-saws, and trowels.

62. Spiller Bros., St. John, New Brunswick, Canada.

EDGE TOOLS.

Report.—Commended for quality and finish.

63. J. E. Straus & Co., Philadelphia, Pa., U. S.

GALVANIZED HODS, CHAINS, AND NAILS.

Report.—Commended as excellently well done.**64. Fagersta Iron and Steel Works, Fagersta, Westanfors, Sweden.**

MILL, CROSS-CUT, CIRCULAR, AND PIT SAWS AND STONE-HAMMERS.

Report.—Commended as of good quality and finish, and made of Bessemer steel.**65. Joseph Warnock & Co., Galt, Ontario, Canada.**

AXES AND EDGE TOOLS FOR WOOD, IRON, AND STONE.

Report.—Commended as of excellent design and superior workmanship.**66. Ahearn & Walsh, Ottawa, Canada.**

LUMBERMEN'S TOOLS.

Report.—Commended as of good quality.**67. Jacques Le Coultre, Sentier, Switzerland.**

RAZORS.

Report.—Commended as of very excellent quality.**68. William Wilkinson & Sons, Sheffield, England.**

SHEEP SHEARS AND GARDEN SHEARS.

Report.—Commended as of first quality and finish.**69. Mayer & Meltzer, London, England.**

POCKET KNIVES, SCISSORS, AND RAZORS.

Report.—Commended as of good quality and finish.**70. Wilson Hawksworth, Ellison, & Co., Sheffield, England.**POCKET AND TABLE CUTLERY, SCISSORS, BUTCHERS' KNIVES, STEELS, AND CHISELS;
MANUFACTURED STEEL FILES AND WIRE.*Report.*—Commended as excellent in quality; manufactured goods well finished and of desirable description.**71. Brookes & Crookes, Sheffield, England.**

POCKET KNIVES, SCISSORS, RAZORS, AND TABLE KNIVES.

Report.—Commended as of elegant finish.**72. George Wostenholm & Son (Limited), Sheffield, England.**

POCKET KNIVES, RAZORS, AND SCISSORS.

Report.—Commended as unsurpassed in quality, finish, and beauty of style.**73. A. S. Whiting Manufacturing Co., Oshawa, Ontario, Canada.**

FORKS, HOES, SCYTHES, AND STRAW-KNIVES.

Report.—Commended as of the highest quality; also patterns and finish highly commended.

74. J. B. Addis & Sons, Sheffield, England.

CARVERS' TOOLS.

Report.—Commended as of superior finish and design.

75. James Burnand & Co., Sheffield, England.

FINE CUTLERY, TABLE AND POCKET KNIVES, AND HUNTING KNIVES.

Report.—Commended as of excellent quality and finish.

76. Star Manufacturing Co., Halifax, Nova Scotia.

SKATES.

Report.—Commended as of excellent quality and finish.

77. John Russell Cutlery Co., Turner's Falls, Mass., U. S.

TABLE CUTLERY, BUTCHER, HUNTING, PAINTERS', AND DRUGGISTS' KNIVES.

Report.—Commended as unsurpassed in quality and finish; also for beauty of design.

78. Miller Brothers Cutlery Co., West Meriden, Conn., U. S.

POCKET KNIVES.

Report.—Commended as good in quality and finish.

79. L. Herder & Son, Philadelphia, Pa., U. S.

MALLEABLE TAILORS' SHEARS AND SCISSORS.

Report.—Commended as good, serviceable goods.

80. The Lamson & Goodnow Manufacturing Co., Shelburne Falls, Mass., U. S.

TABLE CUTLERY, COOKS' AND BUTCHERS' KNIVES.

Report.—Commended as excellent goods; also elegantly finished.

81. Howard W. Shipley, Philadelphia, Pa., U. S.

POCKET KNIVES.

Report.—Commended as excellent in quality.

82. Herrmann Goldschmidt, New York, N. Y., U. S.

RAZOR STROPS OF RUSSIA LEATHER.

Report.—Commended as of excellent quality.

83. Achille Parise, Son, Naples, Italy.

A KEYLESS LOCK FOR SAFES AND STORE DOORS.

Report.—Commended, 1st, as showing very considerable inventive merit, and mechanical skill in construction; 2d, as cheap in cost of production.

84. G. W. Nock, Penn Lock Works, Philadelphia, Pa., U. S.

PADLOCKS AND CAR PADLOCKS.

Report.—Commended as strong and well-made goods; the bell capable of sustaining severe blows without injuring the working of the lock.

85. **W. T. & J. Mersereau, New York, N. Y., U. S.**

STAIR RODS AND DOG COLLARS AND MUZZLES.

Report.—Commended as of good quality and tasteful designs.86. **A. Field & Sons, Taunton, Mass., U. S.**

IRON AND COPPER TACKS AND NAILS.

Report.—Commended as of excellent quality in every respect.87. **American Wire and Screw Nail Co., Covington, Ky., U. S.**

WIRE AND SCREW NAILS.

Report.—Commended as well made and of excellent quality.88. **F. H. Evans, Brooklyn, N. Y., U. S.**

PATENT EXPANSION BOLTS.

Report.—Commended as of good construction and substantially made.89. **W. A. Ives & Co., New Haven, Conn., U. S.**

BRACES, AUGER HANDLES, TAP-BORES, AND AUGERS.

Report.—Commended as very superior in quality and finish.90. **A. G. Newman, New York, N. Y., U. S.**

BUCKMAN'S PATENT SPRING BUTTS, AND FRENCH FLAT INDICATORS.

Report.—Commended as ingenious, simple, and useful.91. **M. Gould's Sons, Newark, N. J., U. S.**

STAIR RODS AND DOG COLLARS.

Report.—Commended as handsomely finished and of tasteful style.92. **H. S. Shepardson & Co., Shelburne Falls, Mass., U. S.**

GIMLET BITS, REAMERS, GARDENERS' SETS, AND GOUGES.

Report.—Commended as superior tools, well made, and useful.93. **American Screw Co., Providence, R. I., U. S.**

IRON, BRASS, AND STEEL SCREWS, TIRE AND STOVE BOLTS, AND RIVETS.

Report.—Commended as of a quality nearly approaching perfection, showing the highest attainments in this branch of manufacture.94. **The Meriden Cutlery Co., Meriden, Conn., U. S.**

TABLE CUTLERY.

Report.—Commended as fine grades and beautifully finished.95. **R. Heinisch's Sons, Newark, N. J., U. S.**

TAILORS' SHEARS AND SCISSORS (MALLEABLE HANDLES).

Report.—Commended as of the best quality and finish.

96. **M. C. Mayo, Boston, Mass., U. S.**

BOSS PLANES AND ADJUSTABLE PLOWS.

Report.—Commended as good and well-finished tools.97. **Benjamin F. Badger & Son, Charlestown, Mass., U. S.**

RAZOR STROPS.

Report.—Commended as very superior in quality and finish.98. **Friedmann & Lauterjung, New York, N. Y., U. S.**

CONCAVE-GROUND RAZORS.

Report.—Commended as well finished and of good style and excellent quality.99. **P. Lowentraut, Newark, N. J., U. S.**

CALLIPERS, COMPASSES, HAMMERS, PUNCHES, AND SHOE-RASPS.

Report.—Commended as well-made and substantial goods.100. **Northfield Knife Co., Northfield, Conn., U. S.**

POCKET KNIVES.

Report.—Commended as beautiful in style and finish.101. **Elmira Nobles' Manufacturing Co., Elmira, N. Y., U. S.**

AXES, DRAW-KNIVES, AND AUGERS.

Report.—Commended as excellent in workmanship.102. **A. & I. Conard, Fort Washington, Pa., U. S.**

AUGERS AND BITS.

Report.—Commended as excellently-made goods.103. **J. Wiss, Newark, N. J., U. S.**

SHEARS, SCISSORS, SHOE-KNIVES, AND PRUNING SHEARS.

Report.—Commended as well finished and of excellent material.104. **Star Lock Works, Philadelphia, Pa., U. S.**

PAD AND TRUNK LOCKS AND DOOR-SPRINGS.

Report.—Commended as of excellent quality and handsomely finished.105. **Barney & Berry, Springfield, Mass., U. S.**

SKATES.

Report.—Commended as of beautiful patterns and elegantly finished.106. **Clarke Combination Lock Co., Baltimore, Md., U. S.**

U. S. SEAL PADLOCKS AND SAFE-DEPOSIT LOCKS.

Report.—Commended as excellent in quality and well adapted for popular use.

107. Wilson Bohannon, Brooklyn, N. Y., U. S.

PAD AND RIM LOCKS.

Report.—Commended as well finished, good, and substantial.

108. The Star Tool Co., Middletown, Conn., U. S.

SQUARES, BEVELS, CALLIPERS, GAUGES, AND MACHINISTS' TOOLS.

Report.—Commended as finely finished, excellent in workmanship, and scales accurately marked.

109. Smith & Egge, Bridgeport, Conn., U. S.

GOVERNMENT PADLOCKS, MORTISE LOCKS, AND SAFETY CHAINS.

Report.—Commended as strongly made and superior in every respect.

110. D. M. Meeker & Son, Newark, N. J., U. S.

MALLEABLE IRON AND OTHER CASTINGS.

Report.—Commended as excellent in quality and finish.

111. Charles Buck, Millbury, Mass., U. S.

FIRMER CHISELS AND GOUGES, PLANE IRONS, AND DRAW-KNIVES.

Report.—Commended as good materials and admirably well finished.

112. Romer & Co., Newark, N. J., U. S.

BRASS AND IRON PADLOCKS AND RIM LOCKS.

Report.—Commended as beautiful and well gotten-up goods.

113. Eagle Lock Co., Terryville, Conn., U. S.

TILL, CUPBOARD, AND OTHER LOCKS.

Report.—Commended as superior in quality of workmanship.

114. Will & Finck, San Francisco, Cal., U. S.

TABLE CUTLERY.

Report.—Commended as substantial and well-finished goods; also tasteful in patterns.

115. American File Co., Pawtucket, R. I., U. S.

MACHINE-MADE FILES AND HAND-CUT RASPS.

Report.—Commended as well made and excellent in quality.

116. Holley Manufacturing Co., Lakeville, Conn., U. S.

POCKET CUTLERY.

Report.—Commended as excellent in styles and finish.

117. Kaliakin & Sons, Pavlovo, Nijni Novgorod, Russia.

TABLE AND POCKET CUTLERY, SHEARS, AND PRUNING KNIVES.

Report.—Commended as highly finished, of excellent quality, and tasteful designs.

118. **Globe Nail Co., Boston, Mass., U. S.**

HORSESHOE NAILS.

Report.—Commended as uniform in size, smooth in finish, and excellent in quality.119. **Demetrius Kondratof, Vatch, Wladimir, Russia.**

TABLE, POCKET, AND OTHER CUTLERY.

Report.—Commended as of common class but excellent quality, and moderate in price.120. **A. Halling, Eskilstuna, Sweden.**

HUNTING KNIVES, KITCHEN KNIVES, AND DIRKS.

Report.—Commended as excellent in quality and finish.121. **F. M. Söderén, Eskilstuna, Sweden.**

SCISSORS AND SHEARS.

Report.—Commended as remarkably well finished and of good quality.122. **J. F. Lindström, Eskilstuna, Sweden.**

CUTTING NIPPERS, PLYERS, PINCERS, AND SHOE-PUNCHES.

Report.—Commended as of excellent quality and finish.123. **T. Hessenbruch & Co., Ronsdorf, Germany.**

TOOLS AND SCISSORS.

Report.—Commended as of good quality, well made and finished.124. **F. Wellmann, Altona, Germany.**

CUTLERY.

Report.—Commended as good in quality, well designed, and of moderate prices.125. **B. & O. Liberg, Rosenfors, Sweden.**

SHEARS, SCISSORS, CHISELS, PLANE-IRONS, GOUGES, AND SKATES.

Report.—Commended as of good quality, well finished, and moderate in prices.126. **F. S. Höller & Co., Solingen, Germany.**

CUTLERY.

Report.—Commended as of excellent quality and in great variety of styles and patterns.127. **Heinrich Ottomar Friedrich, Beierfeld, near Schwarzenberg, Germany.**

TINNED IRON SPOONS AND FORKS.

Report.—Commended as well made.128. **Heinrich Böker & Co., Solingen, Germany.**

CUTLERY.

Report.—Highly commendable on account of beauty of patterns, very high finish, and well-set edges, and at moderate prices.

129. Alexis Zavialof, Vorsma, Nijni Novgorod, Russia.

TABLE AND POCKET CUTLERY, SHEARS, AND HEAVY PRUNING KNIVES.

Report.—Commended as very highly finished, of excellent quality and desirable patterns.

130. Thinet, Paris, France.

CUTLERY.

Report.—Commended as of good quality and at low prices.

131. Sommelet, Courcelles, France.

CUTLERY.

Report.—Made at a reformatory school of juvenile offenders: of value as showing excellence under the circumstances.

132. Guillemin-Renaut, Nogent, France.

CUTLERY.

Report.—Commended as well finished and commendable in taste and design.

133. J. Charbonné-Thuillier, Nogent, France.

SCISSORS AND SHEARS.

Report.—Commended as of good workmanship and excellent quality.

134. Thomachot-Thuillier, Nogent, France.

SHEARS.

Report.—Commended as of excellent quality.

135. H. Denizet, Langres, France.

SHEARS AND KNIVES.

Report.—Commended as of good quality and moderate in prices.

136. A. Gallais, Paris, France.

UPHOLSTERERS' NAILS.

Report.—Commended as well finished and of a great variety of good styles.

137. Empire of Brazil Exhibits.

ORNAMENTAL CASTINGS, BOLTS, NUTS, AND WROUGHT-IRON WORK.

Report.—Commended as creditable to the exhibitors.

138. The J. L. Mott Iron Works, New York, N. Y., U. S.

FOUNTAINS, VASES, AND STATUARY.

Report.—Commended as superior in design and quality.

139. J. F. Armbruster, Philadelphia, Pa., U. S.

CASTING MADE FROM TIN WASTE.

Report.—Commended as a new industry, converting into practical use what has heretofore been considered of no value.

140. E. Mills & Co., Philadelphia, Pa., U. S.

BRACE-BITS, SAW-PADS, SCREW-DRIVERS, SPOKE-SHAVES, AND BRUSH-BITS.

Report.—Commended as all of the best quality and finish.

141. W. J. Flanagan & Co., Philadelphia, Pa., U. S.

WRENCHES, NAMED "SAMSON WRENCHES."

Report.—Commended as a very simple yet valuable invention.

142. Stanley G. Flagg & Co., Philadelphia, Pa., U. S.

STEEL, GRAY IRON, AND MALLEABLE CASTINGS.

Report.—Commended as a fine display of excellent castings. The steel castings are of superior quality.

143. Post & Co., Cincinnati, Ohio, U. S.

PADLOCKS, CAR AND DOOR LOCKS, AND HINGES.

Report.—Commended as excellent in quality, carefully fitted, and well adapted for use.

144. J. H. Sternbergh, Reading, Pa., U. S.

BOLTS AND NUTS.

Report.—A large assortment of sizes and patterns of very good quality.

145. Morse Twist Drill and Machine Co., New Bedford, Mass., U. S.

SCREW PLATES, WRENCHES, STOCKS, DIES, AND CHUCKS.

Report.—Specially commended for accuracy and superiority of finish.

146. W. C. Allison & Co., Philadelphia, Pa., U. S.

BOLTS, NUTS, AND SCREWS.

Report.—A great variety of very superior goods in all respects.

147. Hoopes & Townsend, Philadelphia, Pa., U. S.

BOLTS, NUTS, SCREWS, AND RIVETS.

Report.—Commended as of excellent workmanship and quality of material.

148. Pennsylvania Tack Works, Norristown, Pa., U. S.

TACKS AND SHOE NAILS (COPPER AND IRON).

Report.—Commended as most excellent goods.

149. C. Carmoy, Paris, France.

UPHOLSTERERS' AND DECORATORS' NAILS AND ORNAMENTS.

Report.—Commended as excellent in design and finish.

150. Louis Roehle, Dresden, Germany.

KNOBS AND DOOR TRIMMINGS.

Report.—Commended as very beautiful in design and finish.

151. Royal Manufactory of Spain, Madrid, Spain.

SPECIMENS OF LOCKS, HINGES, AND ESCUTCHEONS.

Report.—Commended as beautifully finished and of antique styles and curious workmanship.**152. E. & G. Brooke, Birdsboro', Pa., U. S.**

NAILS, BRADS, AND SPIKES.

Report.—Commended as neatly made and of good quality and well proportioned.**153. Dunbar, Hobart, & Whidden, South Abington, Mass., U. S.**

TACKS, TRUNK AND CLOUT NAILS, HEEL AND TOE PLATES.

Report.—Commended as well made and of good quality.**154. J. B. Shannon, Philadelphia, Pa., U. S.**

BUILDING HARDWARE AND GONGS.

Report.—Commended as finely finished goods.**155. Wheeling Hinge Co., Wheeling, W. Va., U. S.**

WROUGHT BUTTS, STRAP AND T-HINGES, HASPS, AND STAPLES.

Report.—Commended as of good quality and highly finished.**156. Scovill Manufacturing Co., Waterbury, Conn., U. S.**

BRASS BUTTS AND HINGES, PIANO HINGES, AND CASTORS.

Report.—Commended as highly finished and artistic in patterns.**157. Union Steel Screw Co., Cleveland, Ohio, U. S.**

WOOD SCREWS, MADE FROM BESSEMER STEEL.

Report.—Commended as of excellent quality and workmanship.**158. Trenton Lock and Hardware Co., Trenton, N. J., U. S.**

RIM, MORTISE, PAD, TILL, CAR, AND SAFE LOCKS.

Report.—Commended as of superior quality and workmanship.**159. Norwalk Lock Co., South Norwalk, Conn., U. S.**

LOCKS, BOLTS, AND KNOBS, WINDOW AND DOOR FITTINGS.

Report.—Commended as excellent in quality, also in finish.**160. Samuel Chatwood, London, England.**

FIRE AND BURGLAR PROOF SAFES.

Report.—Commended as well made and of good materials.**161. Stafford Manufacturing Co., New York, N. Y., U. S.**

STENCIL COMBINATIONS AND KEY RINGS.

Report.—Commended as of good quality and well made.

162. Union Manufacturing Co., New Britain, Conn., U. S.

BUTT HINGES.

Report.—Commended as finely finished.**163. Gaylord Manufacturing Co., Chicopee, Mass., U. S.**

CABINET, TILL, AND CHEST LOCKS.

Report.—Commended as of excellent quality, and well finished.**164. Mallory, Wheeler, & Co., New Haven, Conn., U. S.**

RIM AND MORTISE DOOR LOCKS, LATCHES, PADLOCKS, AND DOOR KNOBS.

Report.—Commended as very superior goods, fine in finish, and tasteful in design.**165. D. R. Barton Tool Co., Rochester, N. Y., U. S.**

CHISELS, DRAW-KNIVES, AXES, HATCHETS, AND PLANES.

Report.—Commended as good in quality and finish.**166. Hotchkiss Sons, Bridgeport, Conn., U. S.**

CURRY-COMBS, ANIMAL TRAPS, BREAST DRILLS, AND SAW-SETS.

Report.—Commended as excellent in quality, and desirable in patterns.**167. Blake Bros. Hardware Co., New Haven, Conn., U. S.**

BUTTS, DOOR HANDLES, PULLEYS, AND CASTORS.

Report.—Commended as of excellent quality and finish.**168. The Branford Lock Works, Branford, Conn., U. S.**

RIM AND MORTISE LOCKS, LATCHES, AND DOOR KNOBS.

Report.—Commended as of good quality and well adapted for general use.**169. Lloyd, Supplee, & Walton, Philadelphia, Pa., U. S.**

JAIL AND SPRING PADLOCKS, HOLLOW AUGERS, AND FLUTING MACHINES.

Report.—Commended as superior goods.**170. S. R. Foster & Son, St. John, New Brunswick, Canada.**

NAILS, TACKS, AND BRADS.

Report.—Commended as well-made and fair merchantable goods.**171. Pillow, Hersey, & Co., Montreal, Quebec, Canada.**

NAILS, TACKS, BRADS, AND HORSESHOES.

Report.—Commended as of superior quality.**172. G. Gilmore, Côte St. Paul, Quebec, Canada.**

AUGERS AND BITS.

Report.—Commended as of superior style and finish.

173. Patent Nut and Bolt Co., near Birmingham, England.

BOLTS, NUTS, SPIKES, WRENCHES, CLINCH RINGS, AND WASHERS.

Report.—Commended as of excellent material and workmanship.

174. Ward & Payne, Sheffield, England.

CHISELS, BRACES AND BITS, CARVERS' TOOLS, AND SHEEP SHEARS.

Report.—Commended as of excellent quality and well finished.

175. William Baker, London, England.

TURNSCREWS, BITS, AND MATTRESS AND BALING NEEDLES.

Report.—Commended for excellent quality and good styles.

176. Christopher Baker & Sons, Birmingham, England.

COFFIN TRIMMINGS AND DOOR FITTINGS.

Report.—Commended as well-finished goods.

177. William Smith & Sons, Warrington, England.

PLIERS, NIPPERS, VISES, AND DIVIDERS.

Report.—Commended as well-made and serviceable tools.

178. Sargent & Greenleaf, New York, N. Y., U. S.

COMBINATION, TIME, AND OTHER LOCKS.

Report.—The time locks are simple and effective, and are an absolute lock-out to every one until the expiration of the time for which they are set. Their winding is accomplished by the act of setting the mechanism to the hour of unlocking. The combination and other locks are well and strongly made and finely finished.

179. Buck Brothers, Millbury, Mass., U. S.

FIRMER AND SOCKET CHISELS, PLANE-IRONS, AND PUNCHES.

Report.—Commended as fine in quality and beautifully finished.

180. John Booth & Son, Philadelphia, Pa., U. S.

BRACES AND BITS, SPOKESHAVES, TURNSCREWS, AND CHAIR BITS.

Report.—Commended as of the best quality and finish.

181. Penn Galvanic Works (F. & P. F. Chase), Philadelphia, Pa., U. S.

GALVANIZED SHIP HARDWARE.

Report.—Commended as work excellently well done.

182. Van Heukelom & Verweij, Utrecht, Netherlands.

NUTS, BOLTS, AND SPIKES.

Report.—Commended as of very good quality.

183. **Lesjöfors Iron and Steel Co., Långbanshyttan, Sweden.**

WIRE NAILS, BRADS, AND TACKS.

Report.—Commended as of very superior quality.184. **F. A. Stenman, Eskilstuna, Sweden.**

LOCKS, LATCHES, AND BOLTS.

Report.—Commended as of fine finish and quality.185. **Riverside Iron Works, Wheeling, W. Va., U. S.**

CUT NAILS.

Report.—Commended as neatly shaped, well cut, and of good material.186. **L. Sykes & Son, Philadelphia, Pa., U. S.**

NUTS, BOLTS, TURNBUCKLES, AND WASHERS.

Report.—Commended as excellent goods and well made.187. **P. & N. Nicaise, Marcinelle, near Charleroi, Belgium.**

BOLTS AND RIVETS.

Report.—Commended as of excellent quality and finish.188. **Adolphe Fix, Molenbeek-Saint-Jean, near Brussels, Belgium.**

IRON AND BRASS NAILS.

Report.—Commended as of excellent quality.189. **W. & J. Tiebout, New York, N. Y., U. S.**

SHIP HARDWARE (BRASS AND IRON).

Report.—Commended as superior goods and of excellent patterns.190. **John J. Tower, New York, N. Y., U. S.**

PRISON LOCKS, PADLOCKS, WRENCHES, AND PLANES.

Report.—Commended as of excellent quality and very finely finished.191. **American Stair Rod Co., New York, N. Y., U. S.**

STAIR RODS AND FASTENING NAILS.

Report.—Commended as of good quality and tasteful design.192. **William Russell, Cincinnati, Ohio, U. S.**

HORSESHOES, HAND AND MACHINE MADE; ALSO HORSESHOE IRON.

Report.—Commended for a variety of shoes remedying defects in hoofs; also patent rolled iron for hand shoemaking. All highly meritorious.193. **Rhode Island Horseshoe Co., Providence, R. I., U. S.**

PATENT MACHINE-HAMMERED HORSESHOES.

Report.—Commended for a large variety of sizes of horse, mule, and snow shoes, manufactured from selected scraps; also good shape and finish.

194. Wm. E. Quigley, Waterbury, Conn., U. S.

HORSESHOES.

Report.—Commended as of excellent quality and finish.

195. Aaron W. Smith, Manchester, N. H., U. S.

FLEXIBLE HORSESHOES (PATENT).

Report.—A valuable invention of much practical service.

196. S. S. Putnam & Co., Neponset, Mass., U. S.

HORSE NAILS.

Report.—A large exhibit of good, well-made nails; superior quality.

197. National Horse Nail Co., Vergennes, Vt., U. S.

HORSE NAILS.

Report.—Plain and polished, excellently well made, and of good material.

198. Benedict & Burnham Manufacturing Co., Waterbury, Conn., U. S.

ROLLED BRASS AND COPPER AND BRASS AND COPPER WIRE AND CHAINS.

Report.—Commended as very superior and elegant goods.

199. Holmes, Booth, & Haydens, Waterbury, Conn., U. S.

BRASS AND COPPER (ROLLED AND WIRE) RIVETS AND TACKS.

Report.—Commended as superior and well-finished goods.

200. Lewis, Oliver, & Phillips, Pittsburg, Pa., U. S.

WAGON HARDWARE, HINGES, AND BOLTS.

Report.—Commended as well made and of excellent quality.

201. Corliss Safe Co., Providence, R. I., U. S.

BURGLAR PROOF SAFES.

Report.—This is a novel idea in safemaking, and intended to be burglar proof only. The outer shell is something more than hemispherical in form, of very strong iron, of great thickness (five inches cast in a chill). The inner portion is concentric with the outer, and hung in a crane on pivots, having a motion on its center, and horizontally, by which it can be turned to give access to its contents or reversed and brought forward by appropriate mechanism to position for locking. The junction between the two portions is made tight by a ground fit, leaving no chance of introducing any explosive or wedge, and is still further secured by an expanding packing ring or tongue, fitting into a corresponding groove in the outer shell. The lock is also exceedingly well protected against assault, being encased in a heavy burglar proof box attached to the inside of the safe. The metal of which the safe is composed is sufficiently thick and well chilled. Should the lock be forced off, communication is still impossible with the interior of the safe. This safe is radically different in construction and operation from those made for some years past, and offers security from violence, which entitles it to the highest commendation.

202. New Britain Bank Lock Co., New Britain, Conn., U. S.

BANK, SAFE, SAFE-DEPOSIT, DRAWER, AND OTHER LOCKS.

Report.—This is a large exhibit, comprising the Isham Key Register, Pillard dial, and time locks, and locks for other purposes. The bank and time locks are fine specimens of workmanship. The other locks are very well made and finely finished.

203. **Valentine & Butler Safe and Lock Co., New York, N. Y., U. S.**

FIRE AND BURGLAR PROOF SAFES.

Report.—First-class work, well and strongly made. Provided with the usual protection against fire and burglary.

204. **B. Haffner, Sr., Paris, France.**

SAFES AND JEWEL BOXES.

Report.—A full and fine exhibit of fire and burglar proof safes, house or plate safes, and jewel boxes, with combination locks and a time or chronometer lock. These safes, of which there are many specimens of different sizes, are exceedingly well made and fitted. The same may be said of the locks. The burglar proof safes are composed of alternate plates of wrought and hard cast iron, and would offer great resistance to the drill. The fire proof safes have combination locks and are filled with a non-conducting composition. The jewel cases and cash boxes are well made and finished. The plate safe is a model of taste in design and finish.

205. **Yale Lock Manufacturing Co., Stamford, Conn., U. S.**

TIME, SAFE-DEPOSIT, PRISON, DOOR, CLOSET, AND DRAWER LOCKS, POST-OFFICE BOX AND LOCKS, DOOR TRIMMINGS, AND HINGES.

Report.—These are well-made, substantial goods; the better grades are very finely finished, and are well adapted to their intended purposes. The model post-office, together with the boxes and locks, are neat and tasteful in design, and a public convenience. The time locks are very fine specimens of workmanship, and possess every element of security and protection against being opened except at the stipulated time and by the proper person. The door knobs, handles, and trimmings are fine, well-made goods.

206. **Beard & Brothers, St. Louis, Mo., U. S.**

BURGLAR AND FIRE PROOF SAFES (WITH SCREW DOOR).

Report.—The construction of this door affords a security which the square door does not. The safes are constructed of alternate plates of welded chrome steel and iron in the usual manner. The workmanship throughout is of excellent character. These safes have circular doors; are made of welded (chrome) iron and steel; the doors are closed by a screw, and the fit ground. As the door is admitted to be the weakest point in any safe, this circular form, ground fit, and screwed fastenings may be regarded as an additional security in comparison with the square or rectangular, single or double doors, and the screw securing the door being double threaded, one thread one-sixteenth pitch finer than the other, gives a close fit without much risk of jamming. These safes are worthy of notice for their burglar-proof qualities.

207. **Terwilliger & Co., New York, N. Y., U. S.**

FIRE AND BURGLAR PROOF SAFES.—SPECIAL CLAIMS, BURGLAR PROOF SAFES, WELDED STEEL (THE OUTER PLATE OF STEEL), AND IRON REVOLVING BOLTS, DOORS TONGUED AND GROOVED AND PACKED WITH RUBBER OR FELT. THE FIRE PROOF SAFES FILLED WITH THE ORDINARY COMPOSITE FILLING.

Report.—Well constructed, substantially made, and of superior finish.

208. **J. Watson & Son, Philadelphia, Pa., U. S.**

BANKERS', OFFICE, AND HOUSE SAFES; WELDED STEEL AND IRON, TONGUED AND GROOVED DOORS, AND REVOLVING BOLTS. FOR BURGLAR PROOF WORK. FOR FIRE PROOF SAFES FILLED WITH THE ORDINARY COMPOSITION.

Report.—The safes in the exhibit are well made and finished.

209. Marvin Safe and Scale Co., New York, N. Y., U. S.

FIRE AND BURGLAR PROOF SAFES.—BANKERS', OFFICE, AND HOUSE SAFES, JEWEL BOXES, AND COMBINATION LOCKS.

Report.—The burglar proofs are of welded steel and iron, and of the same general construction and arrangement of bolt works as many others, and are strong, well-finished work. The fire proof safes are filled with a fire proof composition, and are well finished and decorated. The safe-locks are good and very low in price. The house safes are very tastefully finished. There is also a spherical safe made of chrome iron.

210. Herring & Co., New York, N. Y., U. S.

FIRE AND BURGLAR PROOF SAFES; BANKERS', OFFICE, AND HOUSE SAFES AND JEWEL BOXES; CHRONOMETRIC AND OTHER LOCKS.

Report.—Special claims: Patent filling for fire and burglar proof work; franklinite used in addition to welded steel and iron in construction; revolving bolts; doors and their opening tongued and grooved and packed with rubber; locks with or without chronometric attachment; detachable lever or stop securing the bolts in case the lock is forced. The time and safe locks are fine specimens of workmanship and afford protection against fraud. The burglar proof work is massive, and every precaution taken against fraud or violence. The office and house safes are very thoroughly made and decorated. The whole exhibit shows good taste and first-class workmanship.

211. Farrell & Co., Philadelphia, Pa., U. S.

SAFE-DEPOSIT VAULT AND BANKERS', OFFICE, AND JEWELERS' SAFES.

Report.—The burglar proof made of welded steel and iron and franklinite is very strong and massive, with revolving bolts. The security of this safe consists in its three walls of an aggregate thickness of nine inches, each door secured by a combination lock, the outside one having a double chronometric lock. The safe-deposit vault is fitted up complete, and forms altogether the most extensive exhibit in the safe department. The fire proof safes are well made and finished, with combination locks, and are filled with concrete. Special commendation is given to the double fire proof safe, which is presumed to be in every respect what its name indicates.

SIGNING JUDGES OF GROUP XV.

The numbers annexed to the names of the Judges indicate the reports written by them respectively.

DANIEL STEINMETZ, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 23, 49, 51, 63, 64, 68, 82, 83, 88, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 120, 121, 122, 125, 137, 140, 141, 142, 143, 144, 145, 146, 147, 148, 151, 152, 153, 161, 181, 183, 184, 185, 186, 193, 194, 195, 196, 197, 198, 199, 200.

CHAS. STAPLES, JR., 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 79, 80, 81, 84, 85, 86, 87, 89, 90, 91, 92, 94, 95, 96, 97, 98, 99, 118, 138, 139, 154, 155, 156, 157, 158, 160, 179, 180, 189, 190, 191, 201, 203, 206, 207, 210, 211.

JOHN D. IMBODEN, 192.

G. L. REED, 45, 46, 47, 48, 50, 52, 53, 54, 55, 56, 57, 58, 77, 78, 93, 159, 162, 163, 164, 165, 166, 167, 168, 169, 202.

DAVID MCHARDY, 21, 22, 24, 25, 26, 27, 28, 29, 59, 60, 61, 62, 65, 66, 67, 69, 70, 71, 72, 73, 74, 75, 76, 119, 123, 124, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 149, 150, 170, 171, 172, 173, 174, 175, 176, 177, 178, 182, 187, 188, 204, 205, 208, 209.

SUPPLEMENT TO GROUP XV.

REPORTS OF JUDGES ON APPEALS.

JUDGES.

JOHN FRITZ, Bethlehem, Pa.
EDWARD CONLEY, Cincinnati, Ohio.
CHARLES STAPLES, JR., Portland, Me.
BENJ. F. BRITTON, New York City.
H. H. SMITH, Philadelphia, Pa.

COLEMAN SELLERS, Philadelphia, Pa.
JAMES L. CLAGHORN, Philadelphia, Pa.
HENRY K. OLIVER, Salem, Mass.
M. WILKINS, Harrisburg, Oregon.
S. F. BAIRD, Washington, D. C.

1. Chr. Heljestrand, Eskilstuna, Sweden.

RAZORS, KNIVES, AND CORKSCREWS.

Report.—Commended for good workmanship and finish and good quality; made from Bessemer steel.

2. Wm. Demuth & Co., New York, N. Y., U. S.

CAST ZINC AND OTHER FIGURES FOR TOBACCONISTS' AND OTHER SIGNS.

Report.—Commended for beauty and appropriateness of design and skill displayed in fabrication.

3. Ira Buckman, Brooklyn, N. Y., U. S.

AUTOMATIC WINDOW LOCK.

Report.—Commended for simplicity, strength, and security.

4. W. W. S. Orbeton, Wakefield, Mass., U. S.

SCREW BRACE, BLIND HINGES, AND SASH PULLEYS.

Report.—Commended as a strong, secure hinge, and the sash pulley convenient and well adapted to its intended purpose.

5. Ausable Horse Nail Co., New York, N. Y., U. S.

HORSESHOE NAILS.

Report.—Commended for superior quality of iron used in this manufacture; nails well made.

6. Hall's Safe and Lock Co., Cincinnati, Ohio, U. S.

DEPOSIT VAULTS AND SAFES AND CHRONOMETRIC AND OTHER LOCKS.

Report.—Commended for fire proofs, as a patent prepared fire resistant; for burglar proofs, that they are built of alternate plates of welded iron and chrome steel, fastened together by conical bolts. They have interlocking bolts, chronometric attachments to locks, dovetail corners and doors, detachable handles, additional protection from fire of a composition-filled shutter over an air space inclosing the bolt work in the fire proof work. All the above are esteemed valuable improvements. The style and workmanship throughout are of the highest character as to finish and security. The safe-deposit vault is a strong and massive structure, and equal to any exhibited, with its doors well protected by heavy bolt work and combination locks.

7. Metallic Art Works, Boston, Mass., U. S.

BRONZE CASTINGS, NAME PLATES, ETC.

Report.—Commended as fine specimens of castings, tasteful in design, and neatly finished.

8. Stanley Works, New Britain, Conn., U. S.

WROUGHT IRON BUTTS AND HINGES; FLUSH AND OTHER BOLTS.

Report.—A great variety of styles of excellent quality, finish, and design, and embracing some useful improvements.

9. Pottstown Iron Co., Pottstown, Pa., U. S.

CUT NAILS.

Report.—Commended for good quality of iron used and excellent workmanship.

10. J. Neal & Co., London, England.

PATENT PYRO SILVER CUTLERY.

Report.—Commended for the thorough incorporation of the silver with the surface of the steel without the aid of an intervening coating of copper or any other metal, thereby increasing its durability and enabling it to resist injury by sharpening, and for the elegance of their finish and handling in agate and ivory.

11. Colin Pullinger, Selsey, near Chichester, Sussex, England.

SELF-ACTING SIFTER, CASK STAND, AND MOUSE TRAPS.

Report.—A curious collection of very ingenious contrivances, covering a wide range of objects, showing very considerable inventive skill and good workmanship.

12. G. Kent, London, England.

KNIFE-CLEANING MACHINES.

Report.—Commended for efficiency and adaptation to their intended purpose.

13. Alois Winkler, Vienna, Austria.

CAST ZINC LETTERS, EMBLEMS, AND PLATES FOR DESIGNS.

Report.—Commended for good quality of the articles exhibited and tasteful designs.

14. Hombok and Marienthal Ironware Industry and Trade Co., Moravia, Vienna, Austria.

MACHINE-MADE NAILS.

Report.—Commended for general good quality and finish.

15. Joh. Engström, Eskilstuna, Sweden.

RAZORS.

Report.—Commended for good workmanship and style, as well as for good quality of material used.

16. Beecher & Hildersheim, Vienna, Austria.

SAFETY LOCK ON THE KAPPERSDORF SYSTEM.

Report.—Commended for good workmanship and ingenuity of contrivance.

17. Koch & Bein, Berlin, Germany.

CAST ZINC LETTERS, FIGURES, AND COAT OF ARMS.

Report.—Commended for the excellence of the castings and good taste displayed in their ornamentation and finish.

SIGNING JUDGES OF SUPPLEMENT TO GROUP XV.

The figures annexed to the names of the Judges indicate the reports written by them respectively.

CHARLES STAPLES, JR., 2, 3, 4, 6, 7, 8, 10, 12, 13, 14, 17.

COLEMAN SELLERS, 1, 5, 9, 11, 15, 16.

United States Centennial Commission.

INTERNATIONAL EXHIBITION,
1876.

REPORTS AND AWARDS

GROUP XVI.

EDITED BY
FRANCIS A. WALKER,
CHIEF OF THE BUREAU OF AWARDS.

PHILADELPHIA:
J. B. LIPPINCOTT & CO.
1877.

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SYSTEM OF AWARDS

[*Extract from Circular of April 8, 1876.*]

Awards shall be based upon written reports attested by the signatures of their authors.

The Judges will be selected for their known qualifications and character, and will be experts in departments to which they will be respectively assigned. The foreign members of this body will be appointed by the Commission of each country and in conformity with the distribution and allotment to each, which will be hereafter announced. The Judges from the United States will be appointed by the Centennial Commission.

* * * * *

Reports and awards shall be based upon inherent and comparative merit. The elements of merit shall be held to include considerations relating to originality, invention, discovery, utility, quality, skill, workmanship, fitness for the purposes intended, adaptation to public wants, economy and cost.

Each report will be delivered to the Centennial Commission as soon as completed, for final award and publication.

Awards will be finally decreed by the United States Centennial Commission, in compliance with the Act of Congress, and will consist of a diploma with a uniform Bronze Medal, and a special report of the Judges on the subject of the Award.

Each exhibitor will have the right to produce and publish the report awarded to him, but the United States Centennial Commission reserves the right to publish and dispose of all reports in the manner it thinks best for public information, and also to embody and distribute the reports as records of the Exhibition.

ORGANIZATION AND DUTIES OF THE JUDGES.

[*Extract from Circular of May 1, 1876.*]

Two hundred and fifty Judges have been appointed to make such reports, one-half of whom are foreigners and one-half citizens of the United States. They have been selected for their known qualifications and character, and are presumed to be experts in the Groups to which they have been respectively assigned. The foreign members of this body have been appointed

by the Commission of each country, in conformity with the distribution and allotment to each, adopted by the United States Centennial Commission. The Judges from the United States have been appointed by the Centennial Commission.

To facilitate the examination by the Judges of the articles exhibited, they have been classified in Groups. To each of these Groups a competent number of Judges (Foreign and American) has been assigned by the United States Centennial Commission. Besides these, certain objects in the Departments of Agriculture and Horticulture, which will form temporary exhibitions, have been arranged in special Groups, and Judges will be assigned to them hereafter.

The Judges will meet for organization on May 24, at 12 M., at the Judges' Pavilion. They will enter upon the work of examination with as little delay as practicable, and will recommend awards without regard to the nationality of the exhibitor.

The Judges assigned to each Group will choose from among themselves a Chairman and a Secretary. They must keep regular minutes of their proceedings. Reports recommending awards shall be made and signed by a Judge in each Group, stating the grounds of the proposed award, and such reports shall be accepted, and the acceptance signed, by a majority of the Judges in such Group.

The reports of the Judges recommending awards based on the standards of merit referred to in the foregoing System of Awards, must be returned to the Chief of the Bureau of Awards not later than July 31, to be transmitted by him to the Centennial Commission.

Awards will be finally decreed by the United States Centennial Commission, in compliance with the Act of Congress of June 1, 1872, and will consist of a special report of the Judges on the subject of the Award, together with a Diploma and a uniform Bronze Medal.

Upon matters not submitted for competitive trial, and upon such others as may be named by the Commission, the Judges will prepare reports showing the progress made during the past hundred years.

Vacancies in the corps of Judges will be filled by the authority which made the original appointment.

No exhibitor can be a Judge in the Group in which he exhibits.

An exhibitor, who is not the manufacturer or producer of the article exhibited, shall not be entitled to an award.

The Chief of the Bureau of Awards will be the representative of the United States Centennial Commission in its relations to the Judges. Upon request, he will decide all questions which may arise during their proceedings in regard to the interpretation and application of the rules adopted by the Commission relating to awards, subject to an appeal to the Commission.

A. T. GOSHORN,

Director-General.

[*Extract from Director-General's Address to Judges, May 24, 1876.*]

“The method of initiating awards which we have adopted differs in some respects from that pursued in previous exhibitions. In place of the anonymous verdict of a jury, we have substituted the written opinion of a Judge. On this basis awards will carry the weight and guarantees due to individual personal character, ability, and attainments, and to this extent their reliability and value will be increased. It is not expected that you will shower awards indiscriminately upon the products in this vast collection. You may possibly find a large proportion in no way raised above the dead level, nor deserving of particular notice. The standard above which particular merit worthy of distinction begins is for you to determine. In this regard I have only to express the desire of the Centennial Commission, that you should do this with absolute freedom, and when you meet with a product which you consider worthy of an award, we desire you to say, in as few words as you may deem suitable, why you think so.

“This, gentlemen, is all we ask of you in the Departments of Awards. Opinions thus expressed will indicate the inherent and comparative merits, qualities, and adaptations of the products,—information which the public most desires.

“Elaborate general reports and voluminous essays, though of great value as sources of general information, give little aid in determining the reliable or intrinsic merits of particular, individual products.

“The regulations which have been published divide the work of awards into three parts:

“1st. The individual work of the Judges.

“2d. The collective work of the groups of Judges.

“3d. The final decisions of the United States Centennial Commission in conformity with the acts of Congress.

“Each award will thus pass three ordeals, which, doubtless, will be ample and satisfactory.”

GROUP XVI.

JUDGES.

AMERICAN.

S. C. LYFORD, U. S. A.
H. L. ABBOT, U. S. A.
GEO. A. HAMILTON, St. Paul, Minn.

FOREIGN.

WM. H. NOBLE, R. A., Great Britain.
A. LESNE, Belgium.
L. P. DE SALDANHA DA GAMA, Brazil.

GROUP XVI.

MILITARY AND SPORTING ARMS, WEAPONS, APPARATUS OF HUNTING, EXPLOSIVES, ETC.

CLASS 265.—Military small-arms, muskets, pistols, and magazine guns, with their ammunition.

CLASS 266.—Light artillery, compound guns, machine guns, mitrailleuses, etc.

CLASS 267.—Heavy ordnance and its accessories.

CLASS 268.—Knives, swords, spears, and dirks.

CLASS 269.—Fire-arms used for sporting and hunting; also other implements for the same purpose.

CLASS 270.—Traps for game, birds, vermin, etc. (For apparatus of fishing, see Group V.)

CLASS 204.—Explosive and fulminating compounds, in small quantities only, and under special regulations; shown in the building only by empty cases and cartridges. Black powder of various grades and sizes. Nitro-glycerine, and the methods of using and exploding. Giant powder, dynamite, dualin, trinitro-glycerine.

CLASS 205.—Pyrotechnics, for display, signaling, missiles, etc.

GENERAL REPORT

OF THE

JUDGES OF GROUP XVI.

INTERNATIONAL EXHIBITION,
Philadelphia, 1876.

PROF. F. A. WALKER, *Chief of Bureau of Awards :*

SIR,—The Judges of Group XVI. have the honor to submit the following general report upon the part of the International Exhibition committed to them for examination.

Very respectfully your obedient servants,

HENRY L. ABBOT,

Bvt. Brig.-General U. S. A., Chairman.

WM. H. NOBLE,

Major Royal Artillery, Secretary.

GROUP XVI.

MILITARY AND SPORTING ARMS, WEAPONS,
EXPLOSIVES, ETC.

BY H. L. ABBOT.

The exhibits assigned to this group comprised military and sporting arms, weapons, apparatus of hunting, explosives, etc., divided into eight classes, as follows :

1. CLASS 265.—Military small-arms, muskets, pistols, and magazine-guns, with their ammunition.
2. CLASS 266.—Light artillery, compound-guns, machine-guns, mitrailleuses, etc.
3. CLASS 267.—Heavy ordnance and its accessories.
4. CLASS 268.—Knives, swords, spears, and dirks.
5. CLASS 269.—Fire-arms used for sporting and hunting, also other implements for the same purpose.
6. CLASS 270.—Traps for game, birds, vermin, etc. (For apparatus of fishing, see Group V.)
7. CLASS 204.—Explosive and fulminating compounds, in small quantities only, and under special regulations; shown in the building only by empty cases and cartridges. Black powder of various grades and sizes. Nitro-glycerine, and the methods of using and exploding. Giant powder, dynamite, dualin, tri-nitro-glycerine.
8. CLASS 205.—Pyrotechnics, for display, signaling, missiles, etc.

Six Judges were charged with the examination of these and of other military articles displayed at the Exhibition, and with reporting upon the same, viz. :

General H. L. Abbot, U. S. Army, *Chairman*.

Major W. H. Noble, British Royal Artillery, *Secretary*.

Colonel S. C. Lyford, U. S. Army.

Captain L. F. Saldanha da Gama, Brazilian Navy.

Captain Commandant A. Lesne, Belgian Artillery.

Mr. George A. Hamilton, Minnesota.

In submitting a report on the work intrusted to them, the Judges of Group XVI. regret that it was not in their power to apply any practical tests to the various military and sporting arms, explosives, etc., that came under their notice. In the absence of such tests, they do not feel justified in discussing here the relative merits of the different articles which were exhibited in this group, but propose to

confine their observations to a general description of some of the principal objects, and to a brief history of the progress made in small-arms, artillery, and explosives during the past century. For this purpose it has been thought desirable to divide the descriptive portion of the subject by nationalities, and to conclude by treating the historical portion in a general manner.

UNITED STATES.

The exhibit of the United States in Group XVI. was exceedingly full and interesting. The warlike material was chiefly displayed by the Government, but in the class of small-arms, both military and sporting, many private individuals offered fine collections. The Government exhibit was divided between the Engineer, Ordnance, Quartermaster, and Signal Bureaus of the War Department, and the Bureau of Ordnance of the Navy Department. A brief summary of the more interesting articles of each of these displays will be made in turn.

The Engineer Department of the Army exhibited, by models floating in a glass tank and by the actual matériel itself, General Abbot's system of defensive torpedoes adopted for obstructing the channels and harbors of the United States. Interesting models also illustrated the system of trials carried out at Willet's Point, New York, in experimentally developing the subject of submarine mining. The adopted bridge-equipage of the army was shown, together with beautifully executed models of both reserve- and advance-guard trains; also the photographic outfit used by the Engineer troops for copying maps in the field, and the siege and mining tools of the army. This Bureau also exhibited models of gun-carriages devised by officers of the Corps of Engineers, two of which are especially interesting: one, a depressing carriage made by General (then Major) De Russy in 1835, contains the Moncrieff principle which has recently excited so much attention in Europe; the other is the well-known depressing carriage of Major King, adapted to guns of large calibre. The details of the block-houses elaborated by Colonel Merrill, used by the United States in defending important bridges on long lines of railway, also shown by a model, are worthy of careful study.

The Ordnance Department of the Army had an exceedingly full and interesting exhibit. In the classes of heavy and field-artillery the following table furnishes details of the more important guns, but there were many experimental and superseded patterns which well indicated the past and present course of investigation in the United States:

DIMENSIONS.	20-INCH SMOOTH BORE.	THOMPSON 12-INCH BREECH-LOADING RIFLE.	WOODBIDGE 10-INCH MUZZLE-LOADING RIFLE.	SUTCLIFF 9-INCH BREECH-LOADING RIFLE.	MANN 8 4-INCH BREECH-LOADING RIFLE.	U. S. 8-INCH CONVERTED MUZZLE-LOADING RIFLE.	13-INCH SEA-COAST MORTAR.	U. S. 4.5-INCH MUZZLE-LOADING RIFLE.	U. S. 3-INCH MUZZLE-LOADING RIFLE.	PARROT 3-INCH MUZZLE-LOADING RIFLE.
Total weight, pounds.....	115,100	84,280	30,300	44,800	20,000	16,160	17,120	3450	820	890
Length of bore, inches.....	243	192	155	148	144	117	35	120	65	70
Calibre, inches.....	20	12	10	9	8.4	8	13	4.5	3	3
Number of grooves.....		7	19	36	11	15		11	7	3
Feet for one turn.....		70	50	45	60	40		15	11	10
Projectile, pounds.....	1080	600	400	230	168	180	200	30	10	10
Charge, pounds.....	200	120	70	45	30	35	20	3.25	1	1
Powder, kind.....	Hex.	Hex.	Hex.	Hex.	Hex.	Hex.				
Muzzle velocity, feet.....	1386		1350	1417	1406	1411		1280	1232	1232
Preponderance, pounds.....	0		100	0						

The Laidley gun-lift, worked by hydraulic jacks acting upon levers, merits attention as a portable and effective means of dispensing with blocking in mounting and dismounting heavy guns. The collection of artillery projectiles and fuses, also, was especially full and interesting. In machine-guns the Gatling and Hotchkiss patterns, together with many now superseded, were exhibited. In military small-arms the display was peculiarly interesting, being arranged to mark the successive steps of progress since the ante-Revolutionary period. But perhaps the most attractive part of the ordnance exhibit consisted of the gun-making and metallic-cartridge machinery in actual operation. The precision and rapidity of this work is admirable, and well maintains the reputation long held by the United States in this branch. A good collection of instruments employed in testing ordnance was shown in a small laboratory, which was constructed upon a plan designed by Colonel Laidley expressly with a view to a possible explosion. The building consisted of an iron frame covered with boards arranged to yield readily to a force from within. An accident which occurred in 1875 demonstrated the merit of this plan. The instruments are excellent in construction, the chief novelties being Colonel Benton's thread-velocimeter and an improvement upon the Shultz chronoscope, whereby the troublesome mercury break circuit is avoided.

The Quartermaster Department of the Army exhibited, at work, a Warth machine, by which 500 uniform coats, or 1000 pairs of trousers, can be cut daily; also, a screwing-machine for soling shoes; also, a fine cloth-testing machine, devised by General Meigs. An admirable display of uniforms, harness, camp-equipage, and tools was also made. One of the wagons, still in running order, had nearly five

years of active service during the late war, traveling over 4000 miles with the Army of the Potomac and with General Sherman. The veterinary exhibit of this department is worthy of special notice, as showing the system of shoeing in use by the army. It contained many specimens to illustrate the injuries and diseases of the horse.

The Signal Service Bureau made an interesting exhibit, especially of its field-telegraph train, consisting of one battery, four wire-, and four lance-wagons, capable of transporting fifty miles of portable telegraph line; also of its flags, heliographs, and other apparatus for communicating signals for an army in the field.

The Bureau of Ordnance of the Navy made a large and attractive display of material used by that branch of the service. In artillery- and machine-guns the collection was specially designed to give an idea of the successive stages of progress during the past century. The following table furnishes details respecting the larger guns:

DIMENSIONS.	15-INCH SMOOTH BORE.	11-INCH SMOOTH BORE.	9-INCH SMOOTH BORE.	8-INCH SMOOTH BORE.	8-INCH CONVERTED RIFLE.	100-PDR. PARROTT RIFLE.	600-PDR. PARROTT RIFLE.
Total weight, pounds.	42,000	15,700	9,000	6,500	17,275	9,700	5,400
Length of bore, inches	146	131	107	96	126	130	105
Calibre, inches.....	15	11	9	8	8	6.4	5.3
Number of grooves.....					15	9	7
Feet for one turn					40	18	12
Projectile, pounds.....	{ Shot, 440 Shell, 352	{ Shot, 166 Shell, 138	{ Shot, 90 Shell, 74	{ Shot, 64 Shell, 53	Shell, 180	Shell, 96	Shell, 55
Charge, pounds.....	{ 100 35	15	10	7	{ 20 35	10	6
Powder, kind.....	Cannon.	Cannon.	Cannon.	Cannon.	Rifle.	Rifle.	Rifle.
Muzzle velocity, feet..	{ 1560 1160	1,270	1,350	1,330	{ 1270 1450	1,250	1,200

In projectiles, fuses, small-arms, and equipments generally the naval exhibition was extensive and interesting. The display of offensive torpedoes was especially worthy of notice, as it included specimens of all the varieties of that class of weapon now under trial. The Lay and Ericsson torpedoes, which remain under the control of the operator during their run; a fish torpedo of the Luppis-Whitehead type; the Harvey torpedo, a similar device, constructed at Goat Island; and the Barber torpedo; and, finally, the Spar torpedo, as now supplied to our war vessels, were all shown. The small articles, fuses, key-boards, and Farmer's dynamo-electric-machine used for firing completed this interesting display.

Among the more conspicuous of the private exhibits of the United States in Group XVI. may be mentioned that of the South Boston

Iron Co., which maintained its high reputation by a fine display of field-guns and projectiles. Dr. R. J. Gatling showed several of his well-known machine-guns of different calibres, and, especially, a new five-barreled pattern, which contains several improvements, and is well worthy of notice. Among the small-arm exhibits, that of E. Remington & Sons was especially conspicuous from its size; and those of Colt's Fire Arms Manufacturing Co., Sharps Rifle Co., the Whitney Arms Co., Winchester Repeating Arms Co., Providence Tool Co., Smith & Wesson, F. Wesson, and others, well maintained the reputation of American small-arms. Among the novelties may be mentioned the new magazine-guns shown by the Evans Rifle Manufacturing Co., and by Colt's Patent Fire Arms Manufacturing Co.

GREAT BRITAIN.

It is much to be regretted that Great Britain did not attempt any display of its implements of war. The admirable workmanship and thorough efficiency of the ordnance manufactured in England, both in the Royal Arsenal and by private firms, are well known. The 80-ton gun now under trial at Woolwich is the largest piece of rifled ordnance in the world, and the Judges have reason to believe that still larger guns are in course of construction at Elswick by the firm of Sir William Armstrong & Co. The display, however, by Great Britain of sporting arms was both extensive and varied. All the leading manufacturers were represented, and the exhibits fully maintained the character of British sporting guns. Mr. James Purdey, of 314½ Oxford Street, London, showed some very fine specimens of his celebrated shot-guns and express-rifles, illustrative of his snap-action and double-lock. Mr. Alexander Henry, of 12 South St. Andrew Street, Edinburgh, exhibited some admirable specimens of breech-loading express-rifles for deer-stalking and for the destruction of all kinds of large and dangerous game. Messrs. Lang & Sons, of 22 Cockspur Street, Pall Mall, London, exhibited some very fine specimens of their well-known self-cocking double breech-loading sporting guns. Messrs. Lancaster, Rigby, Scott, and Webley were also well represented.

In the British Colonial department there was a general absence of military or sporting arms, but an interesting collection of aboriginal weapons was exhibited by New Zealand.

FRANCE.

In the French department no display whatever of artillery was made, and the exhibits were confined to a few sporting arms and a good display of cartridge-cases by the well-known house of Gevelot.

GERMANY.

The magnificent display by Herr Krupp, of Essen, of heavy and light artillery was unequaled in any former Exhibition. The exhibit consisted of the following articles:

1. 35½-centimetre gun, mounted on barbette carriage and chassis.
2. Long 24-centimetre gun, mounted on barbette carriage and chassis.
3. 8.7-centimetre field-gun, with carriage and limber.
4. Ditto, with carriage only, polished.
5. 7.5-centimetre field-gun, with carriage and limber.
6. 8-centimetre mountain-gun, with carriage, pole, and ammunition-boxes.
7. 6-centimetre mountain-gun, with carriage, pole, and ammunition-boxes, mounted on mules.
8. Saddles and harness for 6-centimetre mountain-guns.
9. A collection of projectiles.

The following table gives the weights and dimensions of the principal parts:

	35.5 CM.	24 CM.	8.7 CM.	7.5 CM.	8 CM.	6 CM.
Total weight, pounds.....	126,766	23,700	1,069	661	227	198
Length of bore, inches.....	270.2	177.6	73.9	70.7	33.3	34.6
Calibre, inches.....	14	9.45	3.42	2.95	3.15	2.36
Number of grooves.....	80	54	24	24	18	18
Weight of projectile, pounds.....	1,125	342	13.7	9.3	8.8	4.4
Weight of charge, pounds.....	275	84	3.3	2.2	0.9	0.4
Muzzle velocity, feet.....	1,591	1,542	1,558	1,496	952	919

RUSSIA.

The Russian Government exhibited an interesting and varied assortment of munitions of war, well selected to illustrate the excellent character of the work done in the arsenals.

The small-arms and metallic-cartridge display showed a perfection of workmanship which leaves nothing to be desired. The parts of the muskets made at different arsenals are interchangeable, and the gauges used in testing are marvels of mechanical accuracy. The greatest novelty was the fortress-rifle devised by Major-General Baron Hahn and adopted by the Russian War Office. It is 0.8 inch in calibre, is loaded at the breech, and fires steel or cast-iron bullets, lead-coated. The recoil is taken up partly by a projection which rests over a sand-bag on the parapet and partly by a movable spring-supported butt-plate. The charge is about an ounce, or one-fifth the

weight of the bullet, which is designed to pierce the sap-roller or iron shield protecting the head of a sap. The swords of the army are also worthy of commendation.

In artillery, the army and navy both contributed specimens, of which the chief details are given in the following table :

DIMENSIONS.	NAVAL 9-IN. BREECH-LOADING RIFLE, STEEL.	NAVAL 6-IN. BREECH-LOADING RIFLE, STEEL.	NAVAL 4-PDR. BREECH-LOADING RIFLE, STEEL.	ARMY 4-PDR. NEW MODEL BREECH-LOADING RIFLE, BRONZE.	ARMY 3-PDR. BREECH-LOADING MOUNTAIN RIFLE, STEEL.	ARMY 8-IN. BRONZE RIFLED MORTAR.	ARMY 6-IN. BRONZE RIFLED MORTAR.	EXPERIMENTAL 4-PDR. STEEL RIFLE FROM PERM WORKS.
Total weight, pounds.....	33,376	8,960	784	1,097	224	8,220	3,600	1,318
Length of bore, inches.....	136	122	60	67	24	54	40	60
Calibre, inches.....	9	6	3.42	3.42	■	8	6	3.42
Number of grooves.....	32	24	12	12	12	30	24	12
Projectile, pounds.....	270	81	12	12	8.8	176	81	13.1
Charge, pounds.....	47	18	1.3	4	0.75	15.3	6.3	5.0
Powder, kind.....	Prism.	Prism.	.....	Coarse.	Fine.	Prism.	Fine.	Coarse.
Muzzle velocity, feet.....	1,341	1,335	1,004	1,537	698	826	800	1,676

This ordnance is all breech-loading, a single cylindro-prismatic wedge and Broadwell ring being used for all but the naval 4-pounder gun, which has a French block. The experimental 4-pounder steel gun shown from the Perm Works is closed upon the Krupp system.

The greatest novelty in this ordnance exhibit was the carriage for the new model chill-cast and mandrel-hardened bronze 4-pounder gun. This carriage, devised by Colonel Engelhardt, is of iron, and is provided with a cork buffer for partially taking up the recoil. It has been severely tested, with good results, and will probably be adopted in the Russian service. The rifled mortars are also interesting. They were cast in a metallic mould under pressure, by the system of Colonel Lavroff. The larger one has been fired 300 times with 17 pounds of prismatic powder, giving a pressure of 1350 atmospheres, and 100 times with 17 pounds of artillery powder, giving a pressure of 2000 atmospheres. The grooves hardly show appreciable wear. The portable traveling-crane for moving ordnance stores exhibited by Mr. Wonlarsky is also worthy of special notice; as is also the fine exhibit of artillery harness. The Perm Works, beside the experimental 4-pounder steel gun, showed interesting models of a 20-inch smooth-bore gun, and of a 9-inch breech-loading hooped steel rifle gun, closed upon the French block system.

The Engineer Department displayed a very beautiful model of the

Russian ponton-train, after the Birago pattern; also numerous elaborate drawings of barrack structures, and of the siege of Sevastopol; also, a model of an iron shield as used at the fortress of Cronstadt; also, the siege and mining tools of the army.

SPAIN.

The Spanish War Office made a very attractive exhibit of war materials.

The magnificent models of fortresses and barracks, contributed by the Engineer Department, were objects of general as well as of professional interest; while the models of the ponton-train, and, especially, of the Birago trestles packed on the back of mules for mountain warfare, excited deserved notice.

In artillery, the details of the mountain-gun were especially interesting. It is of iron, 3.24 inches in calibre, rifled on the French system, and with the French breech-closing mechanism. The carriage is of iron. The pack-saddles for its transportation are peculiar in construction. The models of a 9.7-inch rifled sea-coast-gun, of the field-artillery-equipage, and of sling-carts of various patterns, were beautifully executed.

The exhibition of small-arms used in the Spanish service, and, especially, of the well-known Toledo sword-blades, attracted much attention. The aboriginal arms from the Philippine Islands were also shown.

SWEDEN.

The Swedish Government exhibit possessed much interest; and was supplemented by some specimens of chilled-iron shot, of admirable quality, from the private establishments of Carl Ekman and A. de Maré, and by a fine display of Damascus sword-blades from the Eskilstuna Iron Manufacturing Co.

The models of the military bridge-equipage devised by Captain V. Norman of the Swedish Engineers, and exhibited by the Government, possess novelty,—especially in the peculiar arrangement of the king-bolt of the wagon, by which the front axle may be traversed under the body without requiring an undue reduction in the size of the wheels or building up of the side rails. The self-acting brake is also worthy of notice. In small-arms, a fine exhibit, showing the details of manufacture of the Government rifle at the Royal Factory at Karl Gustafs Stad, was made.

In artillery, some admirable steel hoops for large rifles were displayed by the Motala Mechanical Works Co.; and specimen carriages of a field-artillery-train, complete, were shown by the Government.

The guns, of cast iron banded with steel, exhibit an endurance worthy of the reputation of the Swedish ores. The traces are made of double rope, to serve as drag-ropes in case the battery be crippled by the loss of its horses.

In closing our remarks upon the Swedish war exhibit, it may be well to refer to the admirable lay figures used to display the uniforms of the different corps. They were without a rival in the Exhibition, and in the crowd might easily be mistaken for living men.

BELGIUM.

The exhibition made by Belgium in this group consisted almost exclusively of small-arms, shown by private firms. The excellence and cheapness of the gun-barrels manufactured by the firms of Liége are well known, and have been fully acknowledged at all former Exhibitions. On this occasion, the duty of supporting their country in this national industry was undertaken mainly by the firms of Mairlot & Heuse, and Heuse, Lemoine, & Cie.

SWITZERLAND.

The Swiss exhibit under Group XVI. was confined to small-arms displayed by private parties; especially by the Swiss Industrial Company, which showed samples of the Vetterli and other breech-loading and magazine-guns.

HOLLAND.

The Netherlands exhibit was restricted to military small-arms and swords from the Government manufactory at Delft, and to a magnificent collection of East Indian weapons displayed by the Colonial department.

TURKEY.

The only weapons in the Turkish section consisted of a fine exhibit of rifles, accoutrements, and sabres made at the Imperial Arms Factory of Tophané; and some highly ornamented pistol-holsters and horse-equipments from private parties.

EGYPT.

The Government of Egypt displayed some interesting weapons, more particularly samples of the magnificent antique Damascus blades so celebrated in history, and some richly ornamented dromedary, horse, and donkey saddles and equipments. Also, some modern weapons used in desert warfare. The contributions from the National Museum of Cairo were especially attractive.

BRAZIL.

The exhibition of war material from Brazil was almost exclusively made by the Government, and showed a degree of mechanical skill and progress in that country not generally suspected.

A model of one of the 300-pounder Whitworth rifles now manufactured at the Rio Janeiro Arms Arsenal is beautifully made, and, with three smooth-bore mortars and three muzzle-loading field-guns rifled on the French system, gives a good idea of the ordnance of Brazil.

In small-arms, and in projectiles for cannon, a fine display was made; also in fuses and metallic cartridges manufactured at the Pyrotechnic Laboratory of Campinho.

TUNIS.

The display from Tunis was of great historical interest, consisting of antique guns and pistols, richly inlaid, and of magnificent Damascus swords, some of which probably date from the time of the Crusades. Gorgeously-embroidered horse- and mule-equipments added to the distinctive character of the exhibit.

JAPAN.

The exhibit from Japan under Group XVI. was made entirely by private parties, and consisted of swords, armor, bows and arrows, and other weapons in use before the nation opened her ports to foreigners. The display had much popular interest.

MILITARY SMALL-ARMS.

To trace in detail the development and perfection of military small-arms during the past one hundred years, in the various countries represented at this Exhibition, and, by means of descriptions and statistics, to give the successive steps of improvement that have led to present stages of efficiency in each, would, if skillfully and impartially done, afford a valuable record for the present as well as a valuable memorial for the use of succeeding World's Fairs, where the same progressive field of human ingenuity shall be again opened to investigation. The preparation of a memoir of so comprehensive a character could not, however, be undertaken and completed in the short space allotted to this Exhibition, as the success of any effort of this kind would depend upon the previous collection, in each of the countries, of authentic detailed information, with the view of putting the mass into shape for international dissemination. In the absence, therefore, of such general preparation at this Exhibition, only a cursory

review of the history of military firearms in this country can be attempted.

The manufacture of military arms was carried on in the United States only to a very limited extent previous to the year 1795, gun-making, like all contemporaneous industries, being then in its infancy. Small-arms for the service of the troops were in those times principally of foreign manufacture. During the troublous period succeeding the Revolution, great anxiety was felt on the subject of properly maintaining the country in a condition of defense, and in 1794 Congress laid an embargo upon the exportation of any "cannon, muskets, pistols, bayonets, swords, cutlasses, musket-balls, lead, bombs, grenades, gunpowder, sulphur, or saltpetre," and encouraged the importation of all such materials by admitting them free of duty. These provisions were continued for several years, and in the mean time the initial steps were taken by the Government for the establishment of national armories at Springfield, Massachusetts, and Harper's Ferry, Virginia.

In 1795 the Secretary of War reported to Congress that the armorers engaged at the Government establishment at Springfield, Massachusetts, in repairing arms and preparing to manufacture the most essential parts of the musket, had made some specimens equal in quality to the manufactures of any country in the world. In order to foster the art, in the interest of national security, contracts with private arms manufacturers to the extent of seven thousand muskets were given out by the Government in that year. The muskets so manufactured were after the model of the French arms, which composed by far the greatest part of those in the national store-houses at the close of the Revolutionary War. The oldest pattern of the French musket then known was the one of 1746. Successive alterations and improvements were made to this model in 1754 and 1763; and, finally, in 1776 or 1777, the French Government decided on a model which stood its ground for a period of nearly forty years, saving only some trifling modifications introduced during the period of the French Revolution. This model of 1777, embodying the gradual improvements suggested by the experience of above a hundred years in the martial nation of France, was in those times considered to be exempt from every essential defect, and, doubtless, not to be susceptible of any decided improvement.

The muskets made at the national armories have, from the foundation of those institutions to the adoption of the present breech-loading rifle, been essentially of French model, with only such minor modifications as the progress of the arts and the experience of the service

have demonstrated to be desirable. The arms furnished by the French Government to the United States during the war with Great Britain in 1812-14 were principally of the old model of 1763, commonly known by the name of the "Charleville" musket. This musket, indeed, served generally as a pattern in this country in the early manufactures of military arms.

In the interest of public policy, the National Government early took under its care the private arms manufacturers of the country, and, by advancing funds to them and letting of contracts for military arms, sought to build up these manufactories as places of reliance in case of national danger. It was deemed important, in order to secure the services of these manufacturers when they might be of the highest necessity, to continue in times of peace to furnish them employment. Many of the individuals of small property who engaged in these contracts were absolutely ruined thereby, and the difficulties were so much greater than had been apprehended that it proved in general a losing business to those concerned. Some of them, however, profited by the assistance rendered them, and, in the absence of workmen who had been regularly brought up to the trade of gun-making, original tools and modes of executing various parts of the work were contrived, adapted to the inexperience of the hands, and calculated to obviate the necessity of employing exclusively men who had been bred to the trade. Some of these inventions proved to be valuable improvements in the art, and were gradually disseminated and adopted into general use. In order to secure to the Government workshops the highest class of skilled workmen, an act was passed by Congress in 1800 prohibiting, under penalty of fine and imprisonment, the enticing away from the national armories or employment of any workmen under engagements at those places. To the same end, also, these workmen were exempted by the same act from all military and jury duty during their employment.

The want of competent skilled labor in the various industrial arts in this country gave rise, as above intimated, to great activity and progress in the adaptation of machinery to the performance of mechanical operations and processes. The toilsome labors of hand-production which, up to the beginning of the present century, had been the almost universal practice, began within the first quarter of the century to give way steadily to the more improved methods of manipulation by machinery. The mysteries which theretofore had surrounded many of the arts, and which required years of study and labor to acquire, began to be dispelled; the ingenuity of the intelligent artisan, aided by the wisdom of the scientist and experimentalist,

began its inroads upon previous methods and processes, and in many instances what had theretofore constituted a complete "trade" eventually became broken up into numerous specialties, each complete in itself, but all subordinate to the general calling. This radical division of labor in what had constituted particular trades, gave enlarged scope to the inventor; and thenceforward the general improvement of any established art became dependent entirely upon the direct improvements in its separate subordinate branches. Under the laws for the encouragement and promotion of the useful arts, inventors acquired an absolute property in all inventions made by them, and hence all important improvements became at once matters of pecuniary value to the holders. A constant emulation was thereby engendered and sustained in every branch of mechanical labor.

The art of gun-making kept steady pace with the progress of the times. One of the earliest and most important sets of labor-saving machinery introduced in the national armories was the invention of Thomas Blanchard, of Millbury, Massachusetts. His lathe for turning irregular forms, which was adapted to the turning of gun-stocks, was invented and matured at his own shop in Millbury, and was first built and put in operation at the Harper's Ferry Armory in 1819, and subsequently at the Springfield Armory in the fall and winter of the same year.

Numerous other machines were devised and perfected by this inventor, who was thereafter employed to erect his machinery at the national armories; and on February 7, 1827, he formally relinquished to the United States, for a valuable consideration, all the rights, interests, and privileges which he had in any of the following machines then or theretofore in use at either of the armories: a machine for sawing off the stock to its proper length; one for facing the stock and sawing it lengthwise; one for turning the stock; one for boring the stock for the barrel; one for milling the bed for the breech of the barrel and the breech-pin; one for cutting the bed for the tang of the breech-plate; one for boring the holes for the breech-plate screws; one for gauging the barrel; one for fitting the tang of the breech-pin; one for forming the concave for the upper band; one for dressing the stock and between the bands; one for forming the bed for the interior of the lock; one for boring the holes for the sides and tang-pin; one for turning the barrel and the flats and ovals on the breech of the barrel. This array of machines shows to what extent labor-saving machinery had been introduced in the preparation of gun-stocks at the national armories at this early date.

About the year 1819 another ingenious inventor, John H. Hall,

was employed to proceed to Harper's Ferry Armory to erect machinery for the manufacture of a breech-loading arm of his invention. The arm was invented in 1811, and the machinery for its construction was devised by him after he went to Harper's Ferry. The nature of this machinery can best be understood from the following extract from an official report made by the Colonel of Ordnance to the Secretary of War in January, 1827:

"It is but an act of justice to Mr. Hall, the inventor, to state that during the whole of this period he has devoted himself with the greatest zeal and assiduity to the perfecting of this arm, and of the means for fabricating it, and that in both he has been eminently successful; and to him is due the credit of effecting so great an improvement in firearms.

"The machinery used in the fabrication of these rifles has been constructed upon a new and improved plan, by which a very important improvement in the fabrication of firearms has been effected. By the use of this machinery each of the various separate parts, which when united form one arm, are constructed in that perfectly accurate and uniform manner that every one of the parts of one arm will fit exactly the corresponding parts of any other arm of similar model.

"This degree of perfection in the fabrication of small-arms has ever been considered an object of the highest importance in all national armories, and has been frequently attempted in the armories of Europe, but hitherto without success, and the attempt has been generally abandoned from the belief that the object was unattainable.

"The machinery constructed for and used in fabricating the Hall's rifles executes the work with such exactness that the component parts of one hundred rifles, made some years past, have been joined to other parts, made recently, without the least difficulty, all the parts fitting as exactly as if each had been separately adjusted to the particular rifle thus formed from the scattered members."

This great uniformity of parts was secured by the use of standard metal gauges for each component, whereby the utmost precision was attained through the medium of rigid inspections kept up during the progress of the work. The manufacture of Hall's breech-loading arms continued, under his supervision, at Harper's Ferry until 1844, when, he having died, and a growing sentiment having arisen among the authorities against the use of breech-loading arms, the manufacture entirely ceased. The total number made at Harper's Ferry, from 1820 to 1844, was about twenty-five thousand nine hundred. There were furnished by outside contractors in the same period about twenty-three thousand seven hundred additional. There were still

nineteen thousand eight hundred of these arms on hand, in the arsenals and armories, in 1860.

Hall's arms, although the first breech-loading arms which received any considerable degree of Government patronage in the United States, never enjoyed an unqualified reputation for efficiency in the army. It is extremely doubtful if any considerable number of them were used in the war with Mexico.

The result accomplished by him in his machinery, however, was a matter of very great importance. A gradual reorganization of the machinery at the two national armories was begun as early as 1839, under the supervision of the master-armorers at those places, who were experienced practical mechanics, and by the year 1850 the manufactures at both places were characterized by entire interchangeability. These establishments had been conducted by civil superintendents from their foundation until the year 1842, when the control was transferred to the military supervision of the Ordnance Department of the army. The supervision of the Ordnance Department was superseded by civil superintendents in 1853, who were again supplanted in 1861 by the Ordnance Department, since which time the affairs at the national armories have been administered by that department.

The armory at Harper's Ferry was destroyed by Confederate troops in 1861, and has not since been rebuilt.

With the exception of Hall's arms, and a few Jenks' carbines, all military firearms (muskets, rifles, and carbines) made previous to 1840 were muzzle-loaders, and the ignition was by means of the old flint-lock. The first production of percussion arms at the armories was in 1844. Up to that date there had been manufactured at these two places from their institution an aggregate of seven hundred and fifty-eight thousand flint-lock muskets alone, besides rifles and pistols. Flint-locks were discarded in the manufactories after the year 1844, and subsequently large quantities of the flint-lock arms on hand were transformed to use the percussion principle.

In 1842 rifling of muskets was begun at the armories, and, in 1855, a model rifled musket was adopted and manufactured by the United States in large quantities, and became eventually the infantry arm of the great War of the Rebellion, 1861-1865.

A general distrust of breech-loading arms of all classes, in the then state of the art, was entertained by the military authorities from a period anterior to the dissolution of the Hall's factory in 1844, and continued down to the period of the War of the Rebellion. A board of ordnance officers having under consideration the subject of Colt's

and Jenks' carbines in 1846,—these arms having been brought to the attention of the War Department in 1838 and 1839, and trials in the field having in the mean time been made with them,—reported as follows :

“ After duly considering the subject, the Board have the honor to report that there have been innumerable trials made of arms loading at the breech. The principal advantages of these kinds of arms are a greater and more exact range with less recoil. This results from their being fired with a ball which fits exactly, or slug, which allows the charge to be reduced. It is necessary to add that, when the mechanism is well contrived, they may be handled with ease and quickness,—an advantage of some importance, but often greatly exaggerated. Unfortunately, these advantages appear difficult to obtain with sufficient solidity, simplicity, and durability.

“ The first trials of these arms were anterior to the flint-lock. The application of this principle has been made in various ways, but the almost innumerable varieties may be classed under three heads :

“ 1st. Those with an opening on the top of the barrel.

“ 2d. Those with an opening at the rear end of the barrel.

“ 3d. Those in which the chamber is raised or moved from the line of the barrel, so as to allow the introduction of the charge.

“ The same general objections have been found to exist to all these methods, viz. : Want of solidity of the parts most exposed to the action of the charge, the liability of the movable parts to become unserviceable by their getting fast from rust or dirt deposited at each discharge, and the escape of the gas through the joints or junctions of the different parts. The defects inherent to this method of loading have been such that, notwithstanding the repeated trials made with it for centuries and the many ingenious and well-executed contrivances offered of late years, of which those of Hall, Colt, and Jenks, in this country, deserve mention, this method has not been adopted for arming troops in any country, except partially in this, nor has it been brought into general use for other purposes. In France there are a great variety deposited in the Musée d'Artillerie, among others the Amusette of Maréchal Saxe, the principle of which is very similar to the one now under discussion. The authority of Maréchal Saxe in all that related to war caused the fabrication of a number of these arms. The dragoons of his regiment were armed with a carbine on the same principle, and the marine received a great number in their arsenals. Experiments on a large scale were unfavorable, and their use was abandoned.

“ In 1831 a ‘ fusil de rempart ’ (wall-piece), loading at the breech,

was adopted in France, but when tried more extensively it was found not to answer, and has also been abandoned. Trials made of late years to adapt a carbine of this kind for the cavalry have not proved favorable. Such being the facts, this Board, charged with the duty of prescribing the kind and quality of arms to be provided for our troops, must be thoroughly satisfied that an arm loading at the breech is free from the defects which have heretofore prevented their general use before they can recommend to the War Department to go to the expense of making so great a change in our arms."

In November, 1850, an Ordnance Board, having six varieties of breech-loading arms under trial at Washington, D. C., recommended Sharps rifle for trial with the troops, and some carbines of this pattern were purchased and placed in the hands of mounted men for the purpose; but in July, 1854, the matter being again before an Ordnance Board, they declined to propose any further action on the subject until a decisive report should be received as to the result of the trials in service.

By the act approved August 5, 1854, making appropriations for the support of the army for the year ending 30th June, 1855, the sum of ninety thousand dollars was appropriated "for the purchase of the best breech-loading rifles, in the opinion of the Secretary of War, for the use of the United States army: provided the Secretary of War, after a fair, practical test thereof, shall deem the purchase advisable and proper."

Inventors and manufacturers were therefore invited by advertisement, in September, 1854, to send in specimens of such arms; and, in December, 1854, trials took place at Washington, D. C., resulting in the recommendation by the Board that Sharps and Symmes' arms, presented, be subjected to trial in the hands of troops, and that such trial arms be adapted to the service of cavalry. To these were added the arms presented by Mr. Greene. The arming of infantry troops with any of the systems of breech-loading rifles then extant was not favored by the War Department authorities during this period, and very little of the appropriation for the "purchase of breech-loading rifles" was spent during the term of the then Secretary of War.

Indeed, the military authorities had, in 1855, decided upon adopting, for use in the infantry branch of service, the muzzle-loading percussion-arm, widely known as the Springfield rifled musket of 1855, using elongated expanding ball-cartridges of calibre 58, and the manufacture of these arms in great quantities was immediately begun by the Government. The sentiment of the then Secretary of War on the subject of breech-loaders for infantry service may be gathered

from the following extract from a speech of his in the Senate, made after he had retired from the secretaryship.

"The infantryman," says he, "who has space enough and is in proper position to load his piece at the muzzle, I think, is better served with a muzzle-loading piece than a breech-loading piece. When breech-loading was first introduced the great defect in arms was the difficulty of putting down the ball so as to obtain all the force of the powder to propel it. It was necessary it should be rammed home with great force. Then breech-loading had its value in rapidity of fire, or, at any rate, in putting the ball in, if intended to have rapid firing, so that it should be tight in passing out. All that has been superseded by the introduction of the expanding-ball, which is put in loose in the muzzle, rammed home without delay, expanded by the powder the moment it is ignited, and passes out of the piece tight. There is, therefore, no advantage to the footman in loading a piece at the breech. . . . I object to any alteration upon any new plan of breech-loading of those arms which we have and which we know to be good."

The majority of all the inventions in breech-loading arms put forward previous to 1857 were found to be objectionable after continuous firing, there being no means of preventing the accumulation of residuum in the joints, or of overcoming the liability to failure from the rusting of the joint under exposure. A single particle of rust or residuum in the joint, during the service of the gun, opened a way to the wearing action of the gas, producing permanent injury to the piece. Much uncertainty of fire was also experienced in the various methods of priming of that day. In many specimens, the small vent-holes afforded favorable depositories for residuum, rust, or moisture,—which operate with equal effect to render the arm for the time being ineffectual or useless. The difficulties of the breech-loading problem were not fully overcome until the invention of self-primed expanding metallic cartridges. Hitherto, efforts to produce a perfect gas check were mainly confined to the gun itself, independent of the cartridge,—the loose ammunition, or paper or linen cartridges of the period, not affording any assistance to that end; but the introduction of the metallic cartridge-case, of copper or other expansible metal, as a means of closing the joint by lateral expansion under the force of the explosion, and the renewal of these cases at each discharge, effected a complete revolution in the production of breech-loading arms,—giving rise to a great many varieties of weapons owing their excellence, if not their origin, to the merits of this peculiar ammunition, and in time superseding altogether the other methods of rendering arms breech-loading.

The earliest varieties of metallic cartridges, as constructed in the United States, had for their primary object the closure of the breech-joint. Some were provided with a flange at the base to facilitate ready withdrawal from the gun after discharge, and all relied upon the old method of ignition by percussion-caps through the medium of the fire-duct as in the old arms; but the generation of ignition at or within the base of the cartridge-case itself was soon hit upon as avoiding in a great measure the contingencies of failure, and the cartridge became the subject of improvement in that respect also.

The advocates of breech-loading arms found much more liberal encouragement in the action of the succeeding Secretary of War, whose term began in 1857. Experiments were almost immediately inaugurated by his direction, at the Government workshops, to test the merits of the more promising systems of breech-loaders presented to his notice; and in 1858 he was active in urging before Congress that an appropriation should be made for the purchase of breech-loading carbines for the cavalry service, and also for the alteration of old arms then in the arsenals so as to make them breech-loading arms for the use of infantry soldiers. It was this last proposition which was so strongly opposed by his immediate predecessor, who was then a Senator in Congress, and from one of whose speeches the above quotation has been made. The appropriations were, however, finally granted; and, from 1858 to 1861, continuous experiments were in progress at the national armories, and before Boards of officers, in the examination and trial of breech-loading arms. These experiments, and the hope of ultimately gaining the exclusive monopoly of Government patronage, had the effect of stimulating the ingenuity of inventors in the production of arms; and although these measures of the Secretary of War were not during his term crowned with entire success, his faith in the value of breech-loading arms as a military armament was in no wise diminished. In his annual report of 1859 he says, "Under the appropriation heretofore made by Congress to encourage experiments in breech-loading arms, very important results have been arrived at. The ingenuity and invention displayed upon the subject are truly surprising, and it is risking little to say that the arm has been nearly, if not entirely, perfected by several of these plans. These arms commend themselves very strongly for their great range and accuracy of fire at long distances, for the rapidity with which they can be fired, and their exemption from injury by exposure to long-continued rains. With the best breech-loading arm one skillful man would be equal to two, probably three, armed with the ordinary muzzle-loading gun. True policy requires that steps should be taken to

introduce those arms gradually into our service, and to this end preparations ought to be made for their manufacture in the public arsenals."

And in his annual report for 1860 he says, "Very frequent and numerous experiments have been made, under my direction, of breech-loading arms; and inventions for this purpose are wonderfully numerous. Many have been rejected, but some plans for breech-loading have been approved, after very numerous experiments, and are now conceded by all who are familiar with them, and capable of judging, to be by far the most efficient arm ever put into the hands of intelligent men. Immediately steps ought to be taken to arm all our light troops with the most improved of these arms.

"I hold it to be an inhuman economy which sends a soldier into the field, where his life is constantly in danger, without furnishing him with the best (not the most expensive) arms that are or can be made. It is no answer to say that our troops cannot be taught to use with skill this character of arm as well as another. It is the practice and drill that make the soldier expert in the use of his arm, and whilst he may attain to great skill with a good weapon, he certainly never can do so with an indifferent one.

"I think it may be fairly asserted now that the highest efficiency of a body of men with firearms can only be secured by putting in their hands the best breech-loading arm. The long habit of using muzzle-loading arms will resist what seems to be so great an innovation, and ignorance may condemn; but as certainly as the percussion-cap has superseded the flint and steel, so surely will the breech-loading gun drive out of use those that load at the muzzle. For cavalry the revolver and breech-loader will supersede the sabre."

The following list shows the purchases made by the Government of breech-loading arms during the nine years preceding the war, being the period when inventive ingenuity in that direction began first to be spurred by Congressional legislation. It was during this period that the foundation was laid for the armament of the cavalry with the improved breech-loading arms, which rendered that branch of service so efficient during the late War of the Rebellion:

- 1852.—200 Sharps carbines.
- 1854.—200 Greene's carbines.
- 1855.—400 Sharps, 200 Symmes', and 170 Merrill's carbines.
- 1856.—200 Burnside's and 10 Schroeder's carbines.
- 1857.—400 Colt's rifles, 200 Sharps, 100 Greene's, and 50 Joslyns' carbines; and 400 Maynard's and 1400 Sharps rifles.
- 1858.—3040 Sharps and 691 Burnside's carbines; and 20 Colt's rifles.
- 1859.—2500 Sharps, 100 Merrill's, and 64 Colt's carbines; and 100 Merrill muskets, 100 Merrill rifles, and 288 Colt's rifles.

1860.—1000 Joslyns' and 300 Smith's carbines.

Besides these, the Government purchased the right to make or alter from old arms the following at the Government workshops, viz. :

1858.—Right to alter 2000 muskets or rifles according to plan of George W. Morse; right to alter same number of muskets and rifles on plan of W. Mont Storm.

1860.—Right to manufacture 3000 carbines, and metallic cartridge-cases for same, on patents of George W. Morse.

The manufacture of the standard muzzle-loading rifled musket of the model of 1855 was steadily in progress at the national armories at the breaking out of the War of the Rebellion in 1861; and the productive energy of the remaining establishment (the Harper's Ferry Armory having been destroyed in the first months of the war) was taxed to its utmost to supply this standard rifled musket to meet the increasing wants of the service. In the face of open hostilities and the extraordinary demands resulting therefrom, there was left no time for continuing experiments with unperfected systems of breech-loading for infantry service, nor to contrive and construct new and untried machinery for the production of arms of that character. These experiments were, therefore, discontinued by the Government; but they were industriously pursued by private enterprise during the whole period of the war, resulting in the production of many ingenious weapons, which were largely patronized by the Government for use in the cavalry service. The demand for the regulation muzzle-loading arms made by the Government for the infantry service became so great shortly after the war opened that private contractors had to be called in to duplicate the machinery and aid in the enormous production imperatively needed. The success attained by the use of breech-loaders in the cavalry service, however, had engendered a very strong sentiment by the close of the year 1863 in favor of the introduction of breech-loaders among the infantry regiments. It was not until the fall of 1864, however, that the Government was in a condition to initiate measures looking to a change of its manufactures. The most economical plan then deemed expedient (as previously considered in 1858) was the alteration of the stock of muzzle-loaders then on hand to breech-loading arms. In October, 1864, the Chief of Ordnance of the army reported to Congress, through the Secretary of War, as follows :

“ The use of breech-loading arms in our service has, with few exceptions, been confined to mounted troops. As far as our limited experience goes, it indicates the advisability of extending this armament to our infantry also; and this experience is corroborated by that of several foreign nations, into the military service of which the

breech-loader has been or is about to be introduced as the exclusive firearm for both cavalry and infantry. It is, therefore, intended to make this change of manufacture at our national armories as soon as the best model for a breech-loading arm can be established by full and thorough tests and trials, and the requisite modifications of the present machinery for fabricating that model can be made.

"The alteration of our present muzzle-loading arms is also a very desirable measure, both on account of economy and improvement in the character of these arms. It is thought that they can be altered at a moderate cost, and in a short time, to very efficient breech-loading arms. The details for effecting both these measures will receive the early attention of this Bureau."

A Board of officers was convened at Springfield Armory, in January, 1865, to "examine, test, and recommend for adoption a suitable breech-loader for muskets and carbines, and a repeater or magazine-carbine." Experiments had been in progress at the armory by the master-armorer since the fall of 1864 in perfecting a system of altering the muzzle-loading arms on hand, in accordance with a plan that had been suggested by an employee of the armory during the progress of the experiments at that post in 1858. The Board examined and tested a considerable number of specimens of breech-loading arms, and, in April, 1865, recommended the adoption of the "Peabody" rifle, and expressed the opinion that Spencer's magazine-carbine combined more advantages than any other magazine arm presented. The recommendation of the Peabody rifle was not adopted by the War Department, and the manufacture of the Joslyn breech-loading rifle was undertaken at the armory, about three thousand of them being made in 1865; but reports from the field being very unfavorable to this arm its manufacture was discontinued, and measures were taken in July of that year for the alteration of five thousand arms in accordance with the plan that had been the subject of experiment by the master-armorer. One hundred stands of these arms were issued to troops by the end of March, 1866, and a Board of officers having in the mean time been assembled at Washington, D. C., on the subject of altering old arms to breech-loaders, specimens of these arms were laid before them. The Board examined and tested a considerable number of specimens of arms, and selecting preliminarily the Berdan, Remington, Richardson, and master-armorer's plans, they finally agreed upon the Berdan plan as the best.

The War Department, however, selected the Berdan, Yates, Remington, Roberts, and master-armorer's plan for competitive trial in service, but this recommendation was never carried out. In July of

that year orders were given for the immediate conversion of twenty-five thousand muzzle-loaders to breech-loaders, and the master-armorer's plan (called Allin plan) was adopted for these arms. Orders were at the same time given for the manufacture of metallic centre-primed cartridges for these arms at the Frankford Arsenal, Philadelphia, Pennsylvania.

The preparation of metallic ammunition suitable for these military arms involved the institution of extensive experiments at the Springfield Armory and at Frankford. Not only were the proper form of construction of the cartridge-case itself and the proper method of priming to be selected, but the proper machinery also had to be selected and adapted to the production, in large quantities, of the adopted cartridge. The manufacture of metallic cartridges was a known branch of industry in the United States at the time, the production of ammunition of this character having been undertaken by private enterprise anterior to the war of the Rebellion; indeed, much of it had been used in that war. Large manufactories were in operation in Massachusetts and Connecticut as early as 1863. Ammunition of this class, however, had up to this time been principally of the kind known as rim-primed. It was desirable that the cartridge for military arms should be centre-primed, if one suitable and equally sure of fire could be selected. An original cartridge was devised at the Springfield Armory; but one involving principles of construction that had already been suggested by various inventors was experimented upon and finally adopted for manufacture at the Frankford Arsenal. The machinery for these latter productions had also been, in a great measure, previously suggested by inventors, and through the skill of the practical workmen at the Frankford Arsenal, superintended and controlled by the officer in charge of the post, this machinery was perfected and supplemented so as to increase the production by each set of machines from a small number a day, in the beginning, to more than ten thousand a day when all the improvements were effected.

The manufacture at the Springfield Armory of the newly-adopted breech-loaders progressed as rapidly as the preparations there made and the state of the public funds would admit; and successive improvements in the details of the breech arrangement, and in the reduction of the calibre of the arm, were made at that post up to March, 1870, when a Board of officers convened at St. Louis, Missouri, was directed by the War Department to "examine and report on the best small-arms and accoutrements for the use of the army of the United States." This Board tested a considerable number of arms, including the Remington, Peabody, Roberts, Berdan, Colt, Baxter, Triplett &

Scott, Sharps, Ward-Burton, Martini, Morgenstern, and Conroy breech-loading rifles, and the Remington, Roberts, Sharps, Spencer, and Conroy breech-loading carbines, in competition with the adopted Springfield breech-loading rifles and carbines; and selected the Remington, Springfield, and Sharps as the three principal systems of breech-loading which commended themselves most strongly to the judgment of the Board. One thousand rifles of each of the models, and 1000 Ward-Burton rifles, together with 200 carbines of each kind, were put into the hands of troops for comparative trial under all the vicissitudes of actual field service. In 1873, a Board of officers was convened at Springfield Armory, under authority of an act of Congress, for the purpose of recommending for adoption "a breech-loading system for muskets and carbines." This system was, in the language of the act, to be, when so adopted, "the only one to be used by the Ordnance Department in the manufacture of muskets and carbines for the military service." The following is a list of the arms received and examined by the Board:

LIST OF ARMS.

No. 1.	Wooden model	Edwin Sleeper.
" 2.	Muskets and carbines, calibre .50 (four samples)	General B. S. Roberts.
" 3.	Carbine	W. T. Scott.
" 4.	Magazine-carbine	W. R. Evans.
" 5.	Musket, calibre .50 (two samples) . . .	Sharps Rifle Company.
" 6.	Wooden model	F. W. Worrell.
" 7.	Muskets and carbine (three samples) . .	Peabody Rifle Company.
" 10.	Musket, calibre .50 (four samples) . . .	E. Whitney.
" 14.	Musket, calibre .42	J. D. Greene.
" 15.	Carbine, calibre .42	William Morgenstern.
" 16.	Musket (two samples)	Frederick Wohlgemuth.
" 18.	Musket, calibre .50	John Broughton.
" 19.	Muskets (eight samples)	E. Remington & Sons.
" 24.	Musket, calibre .50	W. H. Elliot.
" 25.	Musket, calibre .50	A. T. Freeman.
" 26.	Musket and carbine, calibre .50 (two samples) .	Ward-Burton.
" 30.	Musket, calibre .50	B. M. Spencer.
" 32.	Musket, calibre .50	W. S. Smoot.
" 33.	Musket, calibre .50	Oscar Snell.
" 34.	Musket, calibre .42	S. F. Van Choate.
" 35.	Musket, calibre .52	W. H. Robertson.
" 36.	Musket, calibre .50	Captain J. M. Whittemore.
" 37.	Musket, calibre .50	John L. Kirk.
" 38.	Musket, calibre .50	Smith & Chamberlain.
" 40.	Musket, calibre .50	B. F. Joslyn.
" 42.	Musket, calibre .50	Updegraff.
" 43.	Musket, calibre .50 (two samples) . . .	Remington-Ryder.
" 44.	Musket, calibre .50	James F. Thomas.
" 45.	Muskets (two samples)	John Broughton.
" 46.	Musket, calibre .42	Westley Richards.

No. 47.	Musket, calibre .50	Schofield-Remington.
" 48.	Muskets and carbines (six samples)	Springfield.
" 49.	Wooden model	Alfred Beals.
" 50.	Musket, calibre .50 (two samples)	I. M. Milbank.
" 52.	Magazine-musket, calibre .44	Stetson.
" 53.	Muskets (three samples)	James Lee.
" 55.	Wooden model	G. R. Remington.
" 56.	Revolving carbine	Helm.
" 57.	Musket, calibre .42	Berdan-Russian.
" 58.	Magazine musket and carbine (two samples)	Ward-Burton.
" 59.	Musket, calibre .50	A. T. Freeman.
" 60.	Musket, calibre .58	Mont-Storm.
" 62.	Musket, calibre .50	Oscar Snell.
" 63.	Musket, calibre .50	Peabody.
" 65.	Musket, calibre .50	Earnest.
" 66.	Musket, calibre .50	Springfield-Stillman.
" 68.	Musket, calibre .50	Springfield-Allin.
" 74.	Wooden model	J. B. Rumsey.
" 76.	Musket, calibre .50	A. T. Freeman.
" 77.	Carbine, calibre .50	E. Whitney.
" 78.	Repeating musket, calibre .45	Winchester.
" 80.	Carbine, calibre .50	W. H. Elliot.
" 82.	Locking rifle, calibre .50	Remington.
" 83.	Musket, calibre .50	Merrill.
" 84.	Musket, calibre .50	William Conroy.
" 85.	Navy rifle, calibre .50	Remington.
" 87.	Magazine-musket, calibre .42	William Gardner.

The following foreign arms were also examined by the Board, from which it will be seen that, so far as the facilities in the way of ammunition would permit, all the principal domestic and foreign systems of modern date were examined and tried:

Chassepot,	Needle-gun,	Needle-gun (improved),
Needle-carbine,	Mauser,	Werndl,
Werder,	Vetterlin,	Martini-Henry.

After the most thorough and exhaustive trials with all the foregoing arms, extending over a period of eight months, and the examination of a great number of reports on the comparative trials then going on in the field, the Board was unanimous in recommending the Springfield breech-loading system for exclusive adoption in the rifles and carbines of the United States military service, and it has been so adopted and used since that time. A classification of breech-loading arms, as made by the recorder of that Board, is herein inserted as of interest in connection with the subject of that class of firearms.

Breech-loading small-arms have (1st) a *fixed chamber*, or (2d) a *movable chamber*, as in the Burnside, Hall, SLEEPER, and WORRELL arms. The movable chamber is now obsolete. The following table shows the divisions of breech-loading weapons having a *fixed chamber*:

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[illegible]

The names in small capitals are those of types submitted to the Board.

N.B.—This list is an abstract of a much more extended one, embracing over one hundred names, from which only prominent examples have been selected, when the docket of the Board failed to present a suitable type for the illustration of the principle involved.

The several varieties of metallic cartridges now in use have been classified as follows :

1st. Those in which the shells are made of continuous metal, combined with a suitable primed anvil, but not reinforced in the head.

2d. Those in which the shells are made of continuous metal, and of combinations of pieces of metal, combined with a primer, with and without a separate anvil, and are also reinforced in the head.

3d. Those in which the body of the case is of continuous metal, and have a solid or other suitable attached head, properly primed.

4th. Those made with a solid head of metal, continuous with the case, and suitably primed.

It is generally conceded that the metallic cartridge of which the bodies are of continuous metal are superior to the wrapped-metal cartridge for military purposes, the latter not being so well adapted to stand the shock of transportation and the incidents attendant upon their carriage upon the person of the soldier.

Immediately after the production of metallic ammunition had begun at Frankford Arsenal in 1866, daily firings were instituted at that post in order to keep the quality of the work up to its highest standard. There gradually grew out of these firings a regular and systematic course of experiments having for its object the improvement of the ammunition in its several features, having respect both to the raw constituent materials and to the actual performance of the ammunition in its completed state. These experiments were of the most prolonged and painstaking description, involving the use of numerous specially-contrived appliances, and of the most highly-improved electro-magnetic and inductive instruments adapted to ballistic research. From the results attained in these experiments, and subsidiary results with rifles of various calibres at Springfield Armory in 1872, a Board of officers was enabled in that year to determine, within limits almost approximating mathematical certainty, the proper calibre, length, weight, rifling, and form of chamber of the gun, and the quality and quantity of the powder, the size, weight, and form of bullet, size and form of metallic cartridge-case, and quantity and quality of lubricant, that would secure in the greatest degree the following qualities, viz.:

- | | |
|--|--------------------------------|
| 1. Accuracy in all winds. | 4. Penetration at long ranges. |
| 2. Cleanliness, or sustained accuracy. | 5. Moderate recoil. |
| 3. Flatness of trajectory. | 6. Lightness of arm. |
| 7. Lightness of ammunition. | |

The results of the labors of this Board were made use of by the

Board which selected the breech-loading system for the arms of the military service.

Having thus sketched in a cursory way the history of the military arms of the United States for the service of infantry soldiers, a word may be added on the subject of pistols and revolvers. Thus far, in treating of firearms, the standard Government arms have been taken as the highest types of such manufactures, the adoption of such arms being in all cases made only after such experiments, competitive and otherwise, on the proving-ground and in actual service in the field, as the resources of Government alone can afford. The development of the pistol has been more the work of private parties.

The earlier pistols used in our service were a class of single-barrel flint-lock arms, worn in holsters attached to the pommel of the saddle. These in time gave way to percussion arms, still single-barreled, and still worn in the holster on the saddle. The invention of the Colt revolving pistol, in 1836, was the first giving any promise of success as a military weapon of this class. Its performances during the Mexican War, in 1847, were far from satisfactory, but by a series of improvements it was brought, by the year 1857, to a pretty high degree of efficiency. It performed a conspicuous part in the War of the Rebellion, where it was very generally used in the cavalry service. Many other revolvers, in principle like the Colt, were put forward during this war. In 1867 the Colt was transformed to use metallic cartridges, and is now one of the adopted arms of the cavalry service. The Smith & Wesson revolver, using metallic cartridges, has also been and is now very considerably used in the cavalry service.

The private enterprise engaged in the production of small-arms has in our day risen to very great proportions. For a detailed description of the most important of the large number of American inventions in breech-loading arms, and the manufactories of the same up to the year 1872, attention is invited to the volume of the report of the United States Commission to the Paris Exposition of 1867, entitled *American Breech-loading Firearms*. The information embodied in this volume regarding this growing industry cannot fail to be of interest to professional men as well as to the general reader. For the details of the experiments made by the Government in breech-loading arms and metallic ammunition, attention is invited to the professional papers and published reports of the Ordnance Department of the army.

SPORTING ARMS.

In few departments of industry has greater progress been made, during the last one hundred years, than is exhibited in the production of sporting firearms, every part of which, from the heel-plate to the muzzle, has been changed, modified, and improved, until, with the present propelling agent, it is believed to be nearly perfect.

The progress in the future will perhaps be in the propelling force. Although gunpowder now holds the first place, the constant experiments with other chemical compounds may eventually produce an agent which, giving greater power, will attain better results, and, superseding gunpowder, will no doubt require a further modification of the gun.

The barrel is the most important part of the gun, and the improvement in its manufacture has been very great. The most celebrated barrels of the last century were those forged by Nicolas Biz and Juan Belez, in Madrid. These were made by forging into a homogeneous mass iron nails from horseshoes, drawing the bloom into strips of proper length, width, and thickness, and welding longitudinally. The fine quality of the iron originally employed in the manufacture of the nails, and the repeated hammering of the small pieces at the forge, in addition to the wear when under the horse's hoof, resulted in the production of an iron of great density and elasticity; and although the fibre was parallel to the axis, the barrels possessed great and enduring strength.

Damascus iron, composed of alternate plates of iron and steel, although not a modern compound, is now generally used for the best barrels. The plates being welded and forged into a bloom, are drawn into rods under the tilt-hammer or between rolls; each rod is then twisted on itself, and three rods with the twist running in different directions are welded together and brought to a proper thickness for the barrel. These strips or ribbons are then wound around a mandrel, welded, and hammer-hardened, and the rough barrel is the result. The process of twisting, rolling, and welding can be carried to a great extent; and if the operations are carefully performed the iron will be improved and the beauty of the figure increased, as shown on the surface when browned. This same figure extends through the whole mass, and will show its beautiful lines wherever the browning preparation is applied. Barrels of great strength, hardness, elasticity, and beauty are produced by welding scraps of mild steel into a bloom, hammering and rolling; and although the repeated heats dissipate most of the carbon, yet the result is a metal of wonderful density.

The progress in barrel-making has resulted in combining in the highest degree strength, lightness, elasticity, hardness, and durability.

The next great improvement, and one which revolutionized the whole system of ignition, was the invention of the percussion principle, in 1807, by Forcyth, of Scotland; and although the percussion-cap was not introduced until about 1820, yet this invention contained the germ of all subsequent advances. The advantages gained over the flint-lock system were the certain and instantaneous fire, and the saving in power by closing the orifice through which ignition was produced. The interior parts of the lock remain the same; and the main- and sear-springs, tumbler, and swivel perform the same functions as in the flint-lock. The last improvement consists in lengthening the top of the mainspring and extending it towards the tumbler; the crank of the tumbler is lengthened beyond the swivel, and projects over the top part of the mainspring. At half-cock the crank of the tumbler rests upon the top of the mainspring, and keeps the hammers from coming in contact with the strikers. This arrangement retains the hammers at half-cock after every discharge, and, by allowing the striking-pins to be withdrawn within the face of the breech, removes all danger of premature discharge while in the act of loading and closing the gun. This improvement is now adopted by all first-class makers, and may be considered a decided success. For simplicity of construction and perfect adaptability to an end the modern gun-lock is a beautiful mechanism.

The breech-loading action, although in principle dating back to a former century, is in its present perfect form the result of the labor and skill of the last thirty years; and its success is due to the production of a cartridge which in itself is a perfect gas check. Introduced into England from France in 1856, the invention of M. Lefauchaux has been modified, improved, and perfected by the skill and genius of many mechanical minds; and although every conceivable mode of fastening securely the barrels to the breech-block has been tried, and a great variety are now in use, yet but one end is to be obtained, and that is the most perfect locking at the moment of discharge between parts necessarily separated. The double bolt under the barrels, combined with the extended top-rib loop-fastening, seems to combine all the requisite strength. The cartridge is the essential part of the breech-loading system.

Within a few years the American system of choke-boring has been revived in England with the most satisfactory results, when not carried to the extreme. The modified choke, as produced by Henry, of Edinburgh, and others, gives an equal and uniform distribution of the

shot, and increases the penetration without sensibly increasing the recoil for the same charge of powder. This system has the advantage of durability, and must supersede the extreme choke, as exhibited in the last "field" trial, being better adapted to all classes of sportsmen than the other. This invention, being certain and constant, dispenses with wire cartridges and concentrators, the irregularity of which was a constant source of disappointment and annoyance. The minor parts of the gun have also been greatly improved. The stock is made more symmetrical, and its strength is increased by the selection of the firmest wood. Horn is substituted for iron in covering the butt, thereby exposing less surface to the action of rust. The tail-piece is attached by a spring, working instantly, securely, and pleasantly, and dispenses with the old socket and loop. The shooting powers have been largely increased, and the perfected breech-loader of to-day is as powerful and effective at sixty yards as the muzzle-loader of thirty years ago was at forty yards.

It is not positively known at what time and by whom the germ of the rifle was invented, but it is certain that, as early as 1498, grooved guns existed at Leipzig; the crowning act of the invention, however, was the introduction, by Augustin Kutler, of the rose-grooved rifle with a spiral form in 1520, and to him belongs the honor of producing a weapon more potent for the purpose of attack and defense than any previous invention, and one which reduces the flight of the projectile to the individual skill of the marksman. The spiral grooves of the rifle give the bullet a rotary motion, in proportion to the force applied and the pitch of the twist. The revolution of the projectile on its own axis keeps that axis in a line parallel to the axis of the bore of the gun, varied only by the power of gravitation and the resistance of the air. Since Kutler's day, the ingenuity and skill of thousands of artisans and many scientific minds have been devoted to the improvement and perfection of the rifle, and the names of Armstrong, Whitworth, Lancaster, Purdey, and Henry stand pre-eminent in the list; but there is hardly a form adopted in the last one hundred years which has not previously been tried with more or less satisfactory results, and the great advance is to be attributed to the perfection of machinery which cuts the spiral grooves with mathematical accuracy, and to science which produces such homogeneous metal for the barrels, rather than to any new principle.

The modern express-rifle is constructed on a principle by which great accuracy and power are obtained; good targets are made up to fourteen hundred yards, and heavy rifles with explosive shells are used with certain effect upon large game. Henry's rifling is the system

generally adopted for these weapons. It consists of seven grooves and one turn of twist in twenty-two inches. It is evident that this great increase of twist must require a corresponding increase of propelling force to overcome the enormous friction, consequently the charge of powder is enlarged to four drachms, materially extending the range. The application of the breech-loading system to the rifle has produced the most satisfactory results. The projectile has no longer to be forced from the muzzle to the breech, but is now inserted in the chamber, and can be made the full size of the bore. The passage from the chamber into the tube causes the operation of rifling to take place immediately and perfectly.

FIELD-ARTILLERY.

The field-artillery used during the American War of Independence, of 1776, consisted mainly of bronze smooth-bore 12-pounders, 6-pounders, and 3-pounders, and fairly represented the field-guns of that period. The present organization, on the battery system, was then unknown, and the artillery of an army consisted of a train, which usually included field- and siege-guns. The former were nominally divided into brigades or regiments, but the guns, for fighting purposes, were distributed among the infantry battalions, and were horsed by hired cattle driven by civic conductors temporarily employed for the purpose. This miserable organization was general in all armies until 1792-93, when horse-artillery was introduced into the French and English services; but battalion guns were retained in the latter service as late as 1802, and in 1799 the two 6-pounders of an infantry brigade were each drawn by three horses in single draught, conducted by a man on foot with a wagoner's whip.

Considerable progress was made in the organization and equipment of field-artillery during the latter part of the eighteenth and early part of the nineteenth centuries, and in the wars of Napoleon field-artillery became a special and powerful arm, possessed of great mobility, and capable, when skillfully handled, of deciding the fate of battles.

Still, although several important improvements were made in the smooth-bore equipment during the long peace which preceded the Crimean War, little was done during the first half of the present century towards introducing a rifled arm.*

* The following note, extracted from the *English Text-Book of the Construction and Manufacture of Rifled Ordnance* (Major F. S. Stoney, R.A., and Captain C. Jones, R.A.), gives a list of the principal inventors of rifled cannon previous to the year 1850:

In the Arsenal of St. Petersburg there is a gun two and three-quarter inches in diameter and sixty-two inches in length of bore, which was rifled in nine grooves in 1615.

Rifled muskets throwing spherical projectiles had long been in use, but it was not until 1846 that the first military small-arm using an elongated projectile was introduced by the French. The adoption of this muzzle-loading rifled musket was followed in 1848 by the appearance of the celebrated Prussian needle-gun; and, within a few years, the armies of the world were equipped with rifled small-arms firing elongated projectiles.

The difficulties in the way of perfecting ammunition and constructing guns were very much greater in the case of ordnance than in that of small-arms; and, although several desultory experiments in this direction had been made, the question of rifled ordnance first assumed a practical shape about the year 1855. Three years later, the first rifled gun, a field muzzle-loader, was introduced by the French; and was followed immediately by the adoption in England of the celebrated Armstrong breech-loading gun. The latter was abandoned in 1870 in favor of a muzzle-loading gun.

It is not in the scope of this paper to discuss in detail the various changes which have been made from time to time in the artillery services of the world since the introduction of rifled arms, but the following tables will show the field armament of the principal nations before the Franco-German War of 1870:

In 1661 the Prussians experimented at Berlin with a gun rifled with thirteen shallow grooves.

In 1696 the elliptical bore was known, and had been tried in various parts of Germany.

In 1745, the date at which Robins was experimenting in England, the Swiss already possessed small rifled pieces.

In 1746 Munich had a rifled breech-loader made, and T. Senner was engaged in rifling various guns.

In 1774 experiments with elongated projectiles, fired from a 6-pounder smooth-bore gun, were carried out at Woolwich by the "Military Society."

In 1776 Dr. Pollock proposed elongated shot for smooth-bored guns.

In 1790 Mr. Wiggin made designs of a rifled gun and belted projectiles.

In 1816-19 M. Pouchara, a distinguished French artillery officer, was making experiments with an old gun rifled with thirteen grooves.

In 1821 Lieutenant Croly, of the British army, proposed breech-loading cannon and lead-coated projectiles.

In 1823-32 Lieutenant Norton, of the English service, proposed explosive shells and a rifled gun.

In 1826 experiments were made with cylindro-conical percussion-shells, designed by Lieutenant-Colonel Miller, of the English Rifle Brigade.

In 1833 M. Montigny, of Brussels, invented a breech-loading rifled piece.

In 1842 Colonel Trenille de Beaulieu first presented to the French Government his plan for rifling muzzle-loading guns, with a few large grooves for studded projectiles, which was afterwards adopted in a modified form by the French service.

In 1845 Major Cavalli, a Sardinian officer, invented a breech-loading gun rifled with two grooves for a ribbed shot; guns on his system were used at the siege of Gaeta in 1860.

In 1846 the Swedish Baron Wahrendorf proposed the system of using lead-coated projectiles with shallow-grooved breech-loaders.

FIELD ARTILLERY IN 1869.

PARTICULARS.	AMERICAN.	ENGLISH.		FRENCH.		PRUSSIAN.		AUSTRIAN.		RUSSIAN.	
	LIGHT.	LIGHT.	HEAVY.	LIGHT.	HEAVY.	LIGHT.	HEAVY.	LIGHT.	HEAVY.	LIGHT.	HEAVY.
Calibre, inches.....	3	3	3	3.41	4.78	3.1	3.6	3.2	3.98	3.42	4.8
Length of bore, inches.....	65	52.5	61.4	55.1	71.4	70.6	70.2	47.7	57.8	51.4	74.4
System of loading.	M. L.	B. L.	B. L.	M. L.	M. L.	B. L.	B. L.	M. L.	M. L.	M. L.	M. L.
Number of grooves	7	38	38	8	6	12	18	6	8	6	6
Total weight of gun, cwt.....	7.32	6	8.5	6.5	15.9	5.8	8.5	5.2	9.8	5.9	15.9
Weight of projectile, pounds.....	9.5	9	11.75	9	28.3	9.6	15.2	8.0	14.5	10	28.3
Weight of charge, pounds.....	1.25	1.13	1.5	1.21	3.16	1.1	1.32	1.16	2.03	1.35	3.16
Muzzle velocity, feet.....	1200	1060	1170	1066	1006	1150	1070	1093	1125	1050	1006

In 1870 England abandoned the breech-loading system and introduced muzzle-loading field-guns, while Russia, on the contrary, to a large extent abandoned muzzle-loading guns and introduced breech-loaders. But little has been done in England since 1870 to develop the power of field-artillery, as measured by the weight and velocity of the projectile thrown; but extensive experiments have taken place both in France and Germany, and both these nations have introduced a new armament for their field-artillery. Austria has also abandoned muzzle-loading guns, and bronze breech-loaders are now being gradually introduced in the Austrian service. The French experiments subsequent to the war were made both at Calais and Bourges; and, at the latter place, the new muzzle-loading 9-pounder English gun was tried in competition with others. The Bourges Committee summed up its conclusions in 1873 as follows:

"In spite of a few imperfections, the English matériel taken as a whole constitutes a system of artillery of the first class. The Woolwich gun, with steel tube and wrought-iron coils, produces results which are not inferior to those of any other field-gun actually in any service in Europe. It is, however, probable that these results may be surpassed. This is the end which we must pursue in the search for a field-gun, and it is indispensable to attain it in case we adopt breech-loading; this system of loading presenting as it does practical disadvantages, should, to be adopted, afford in compensation a very marked superiority over the best muzzle-loading gun."

It appears, therefore, that the French Commission fully recognized

the advantages of a muzzle-loading system for field-artillery, although they ultimately adopted a breech-loading gun.

Notwithstanding the high reputation which the Prussian field-guns obtained during the war of 1870-71, there were many German artillery officers who were dissatisfied with their power; and the experiments which were carried out in England in 1872, in which the German 9-pounder breech-loader was tried in competition with the English 9-pounder muzzle-loader, strengthened this feeling. The German artillery was unanimous in favor of breech-loading; but it was thought that the field-guns which took part in the war were deficient in power, and that the breech-loading system was capable of much greater development. The Berlin Artillery Committee accordingly directed their attention to the defects in the existing guns, and with the assistance of Herr Krupp they appear to have produced an excellent field-artillery equipment. The guns are said to be of great accuracy and power, and, judging from the specimens exhibited by Herr Krupp at Philadelphia, the whole equipment appears to be of a most serviceable description.

The following table gives the dimensions of the guns now in use by European field-artillery:

FIELD-ARTILLERY OF 1876.

PARTICULARS.	ENGLAND.		FRANCE.	ITALY.	PRUSSIA.		RUSSIA.	
	LIGHT.	HEAVY.			LIGHT.	HEAVY.	LIGHT.*	HEAVY.
Calibre, inches.....	3	3.6	3.35	2.95	3.09	3.56	3.42	4.2
Length of bore, inches.....	63.5	68.4	74.1	62.5	74.2	73.4	60.7	57.2
Number of grooves.....	3	3	14	12	24	24	12	16
Weight of projectile, pounds...	9	16	16	8.2	11	16	12.6	24
Weight of charge, pounds.....	1.75	3	2.65	1.21	2.76	3.31	1.5	3.25
Muzzle velocity, feet.....	1380	1355	1312	1312	1522	1460	1004	1000
Total weight of gun, cwts.....	6	12	12.02	6.02	7.68	8.86	6	12.6
Total weight of carriage, cwts..	11.2	12.8	7.39	7.36	9.5	10.25	8.61	.....
Number of rounds carried with gun and limber.....	40	28	32	46	39	33	18	12
Total weight behind team, including gun, carriage, and limber packed, cwts.....	32	41	37	24.6	35	37.7	24.4	.....
System of loading.....	M. L.	M. L.	B. L.	B. L.	B. L.	B. L.	B. L.	B. L.

Rifled mountain-guns have now been generally introduced into European armies. A complete description of the equipment of each country is beyond the limits of this paper, but the following table gives the principal dimensions and weights of the pieces now in use:

* A new bronze breech-loading rifled gun has been approved, and is in process of introduction into the Russian service. The charge will be about four pounds, giving a muzzle velocity of 1530 feet.

PARTICULARS.	ENGLISH.	AUSTRIAN.	FRENCH.	ITALIAN.	RUSSIAN.	SPANISH.
	7-PDR.	3-PDR.	4-PDR.	8-CM.	3-PDR.	8-CM.
Calibre, inches.....	3	2.92	3.4	3.4	3	3.4
Length of bore, inches.....	36	35.8	31.7	35.8	24	31.6
Number of grooves.....	3	6	6	6	12	6
Total weight of gun, cwts.....	1.78	1.71	1.97	1.97	2	1.97
Material of gun.....	Steel.	Bronze.	Bronze.	Bronze.	Steel.	Bronze.
System of loading.....	M. L.	M. L.	M. L.	M. L.	B. L.	M. L.
Weight of projectile, pounds.....	7.3	6.2	8.8	6.5	8.8	8.9
Weight of charge, ounces.....	12	7.4	10.6	10.6	12	12.3
Muzzle velocity, feet.....	955	794	771	879	698	.....

A highly interesting and valuable series of field-artillery experiments was carried out in the autumn of 1875, at Okehampton, in England. The object of these trials was to ascertain the effect of artillery fire under circumstances as regards ground, etc., that would represent, as far as possible, the conditions of actual war. For this purpose two batteries of Royal artillery were encamped for about a month on Dartmoor, in Devonshire. These batteries, day by day, drew their ammunition from a field-magazine, and manœuvred over all sorts of ground, coming into action in various positions and at different distances, the sites of the objects fired at being also varied so as to obtain as closely as possible a representation of the effects of fire under all circumstances that might occur on service. The objects consisted of wooden dummies representing infantry soldiers, and wooden targets to represent cavalry. The batteries depended for their knowledge of distance on observation alone, using for the purpose Nolan's range finder. The results of these important trials may be summarized as follows:

1. Both time- and percussion-shells are indispensable to the efficiency of field-artillery. The destructive effect of a good time Shrapnel against troops in any loose formation, and presumably in motion, is greater than that of a percussion-shell burst on graze. Against column formations, when the range is known, both projectiles appear to be equally efficient. The time-shell has the advantage when firing at batteries or troops retired behind the crest of a hill. When firing at objects in motion, the effect of time Shrapnel depends greatly on the accuracy with which the varying distances are estimated, upon the care and judgment in boring or setting the fuse to correspond with these conditions, and upon the facilities for observing the value of each shell as regards height and distance of the point of bursting from the object. On the other hand, the extreme simplicity of good percussion-shells and the valuable aid they offer in readily picking

up and varying the range are advantages that cannot be over-estimated, and render a projectile of this nature especially valuable for use in the excitement and heat of action. The chief disadvantage in the employment of percussion-shells arises from the uncertainty due to the nature and formation of the ground on which the shell may graze, and the possibility of its proper action being seriously interfered with or altogether nullified.

2. Bodies of troops cannot with impunity remain stationary, or even move deliberately, in front of rifled guns at any distance under four thousand yards, if the ground be all open, provided the artillery be so posted that they can see for that distance and the atmosphere be clear. Villages or depots of stores would be unsafe at longer ranges.

3. Under favorable circumstances of weather and of open ground, such as it may fairly be assumed an attacking force would have to traverse, it would be impossible without great loss to maintain column formation under the fire of rifled artillery at any distance under four thousand yards. Under these circumstances of weather and ground a well-sustained and concentrated fire of rifled field-artillery would prove most formidable to the advance of troops in any formation. Even against skirmishers well-served time Shrapnel could be used with considerable effect at ranges under two thousand yards.

4. A strong battery of rifled field-artillery can take care of itself, provided its flanks are protected and the ground in its front is moderately open.

5. It is most important that every field-artillery battery should possess the means of ascertaining distances. The instruments used for this purpose should be accurate, simple, and portable. It should, however, be borne in mind that no amount of simplicity or portability will compensate for inaccuracy. An instrument that will not find the range correctly is only in the way. But the possession of a trustworthy means of ascertaining distances should never be allowed to interfere with the practice of judging distance by eye. There will be many occasions where range-finders cannot practically be used at all, and the true method of teaching gunners to lay guns is to constantly and carefully practice them in the art so as to fix it indelibly upon their minds. There can be little doubt that field-artillery has a great future before it, and that when skillfully handled it will produce surprising results. To all appearance it has now arrived at perfection so far as regards power and mobility; but it is possible that within a few years steam may play a part in field-artillery, and that we shall live to see far heavier and more powerful guns than the present pieces brought into the field by traction-engines.

SIEGE-ARTILLERY.

The experience derived from the Franco-German War of 1870, and from recent experiments both in Germany and England, will doubtless result in considerable modifications being made in the rules as now laid down for the conduct of sieges. The marvelous accuracy of modern artillery will render the use of the embrasure a practical impossibility, except under peculiar circumstances of position and distance; and the production of a simple and strong siege-carriage, from which direct fire can be obtained with the minimum exposure of gun and detachment, is recognized to be a great desideratum. Of late years much attention has been given to the subject of rifled siege-artillery, particularly rifled mortars, and the following table gives the weights and dimensions of various pieces now in use.

TABLE GIVING THE WEIGHTS AND DIMENSIONS OF SIEGE-ARTILLERY, 1875.

NOTE.—The following abbreviations are used: S. and W. I. = steel and wrought iron. S. = steel. B. = bronze. C. I. = cast iron.

NATIONS.	CALIBRE, INCHES.	LENGTH OF BORE, INCHES.	NUMBER OF GROOVES.	WEIGHT OF SHELL FILLED, POUNDS.	BURSTING CHARGE, POUNDS.	TOTAL WEIGHT OF GUN, CWTs.	SERVICE CHARGE, POUNDS.	MATERIAL OF GUN.	SYSTEM OF LOADING.	MUZZLE VELOCITY, FEET.
UNITED STATES.										
100-pounder Parrot.....	6.4	130	9	101	5.5	86.6	10	C. & W. I.	M. L.	1250
30-pounder Parrot.....	4.2	120	5	29	1.5	37.5	3.2	C. & W. I.	M. L.	1293
4½-inch gun.....	4.5	120	11	25.5	1.5	30.8	3.2	C. I.	M. L.	1303
ENGLAND.										
64-pounder.....	6.3	97.5	3	64.6	7	64.5	10	S. & W. I.	M. L.	1375
40-pounder.....	4.7	85.5	3	38	2.6	35	7	S. & W. I.	M. L.	1336
8-inch howitzer.....	8	48	4	180	13	46	10	S. & W. I.	M. L.	790
FRANCE.										
24-pounder.....	6	79.2	6	52.9	2.2	40.4	5.5	B.	M. L.	955
12-pounder.....	4.8	78.9	6	25.3	1.1	17.1	2.6	B.	M. L.	1040
GERMANY.										
15-centimetre long.....	5.9	119.6	37	61.7	4.2	59	13.2	S.	B. L.	1542
15-centimetre short.....	5.9	73.9	24	61.1	4.4	29.5	3.3	S.	B. L.	830
12-pounder.....	4.7	75.3	18	32	1.1	17.1	2.3	B.	B. L.	978
21-centimetre gun.....	8.2	114.5	30	174	10.5	76	14.3	S.	B. L.	984
21-centimetre mortar.....	8.2	.....	30	174	10.5	34.8	4.4	B.	B. L.	545
RUSSIA.										
24-pounder.....	6	113.9	24	64.2	2.6	42	6.3	S.	B. L.	.....
12-pounder.....	4.8	84	18	32	1.2	18.5	3.1	B.	B. L.	1006
8-inch gun.....	8	113.5	30	176	6.1	102.2	17.2	S.	B. L.	1050
8-inch mortar.....	8	54.2	30	176	14	78.2	15.3	B.	B. L.	826
ITALY.										
16-centimetre.....	6.5	107	6	65.2	2.6	60.5	7	C. I.	M. L.	1092
12-centimetre.....	4.8	76.4	6	24.6	1.1	14.4	2.6	B.	M. L.	1117
22-centimetre howitzer.....	8.8	78.3	6	154.3	7.7	55.5	7.7	B.	M. L.	732
AUSTRIA.										
24-pounder.....	5.9	87.1	30	60.8	2.2	30	3.4	C. I.	B. L.	804
12-pounder.....	4.7	98.3	24	30	1.2	29.3	2.4	C. I.	B. L.	570
8-inch mortar.....	8.2	60.1	30	193	8.9	98.8	11.1	C. I.	B. L.	718

HEAVY ORDNANCE.

At the termination of the memorable siege of Gibraltar, about ninety-six years ago, the serviceable and mounted armament of the fortress consisted of the following natures of cast-iron smooth-bored ordnance,—which represented the heavy artillery of the period :

Guns : 32-pounders, 24-pounders, 18-pounders, and 12-pounders.

Mortars : 13-inch, 10-inch, and 8-inch.

Land-service howitzers : 10-inch and 8-inch.

At the great siege of Sebastopol, fifty-eight years afterwards, the artillery used on both sides, with the exception of a few Lancaster rifled guns employed by the British, were cast-iron smooth-bored pieces somewhat similar in general character to the guns used at Gibraltar. Thus, over half a century had passed without any marked improvement in the power of ordnance. This stagnation, however, must not be attributed to ignorance of the theory of gunnery, but to the want of suitable materials and proper machinery for the manufacture of larger and more powerful guns. Moreover, this period was not altogether one of inaction. General Paixhan, in 1822, pointed out the advantages of horizontal shell fire, the development of which ultimately led to the introduction of ironclads. General Rodman also—one of the pioneers of “*Armed Science*”—introduced the celebrated cast-iron smooth-bored ordnance which bears his name, and thus placed the United States for some time at the head of the nations of the world in the matter of powerful ordnance. It must, however, be admitted that the first practical step that led to the vast development which has of late years taken place in heavy ordnance was the substitution of the elongated for the spherical projectile.

Many attempts were made to rifle existing cast-iron smooth-bore guns by grooving the bore, and apparently strengthening the piece by superimposed iron breech-rings ; but all those attempts were mainly due to a tendency to utilize the stock on hand,—and the trials in this direction showed that cast-iron guns thus rifled could not be depended upon when using high charges. Still, good results have been obtained by lining cast-iron guns with tubes of coiled wrought iron or steel, as proposed by Sir William Palliser and Captain Parsons, and recent improvements in gunpowder may render these systems applicable to very heavy guns.

The great progress, however, which took place in the manufacture of cast steel, and the introduction of the steam-hammer, enabled the artillerist to forge the monster weapons of the present day, and to produce trustworthy guns of vast size and power. This great develop-

ment in the power of attack has advanced *pari passu* with a comparative increase in power of defense. The introduction of horizontal shell fire led to the use of armor on the sides of ships of war; and the memorable trial of the "Warrior" target in England, in 1862, showed that the defense had succeeded in producing a vessel that was proof against the most powerful rifled or smooth-bored guns then in Europe. This triumph, however, was but short lived. Within a few months, Sir Joseph Whitworth produced steel shells which perforated the "Warrior" target with ease; and, since that date, the question of guns *versus* armor has been one of an oscillating character, according as thicker plates or more powerful guns have, from time to time, been produced. The "Warrior" with 4½-inch plates was followed by other vessels protected successively with 6-inch, 7-inch, 8-inch, 9-inch, 10-inch, 12-inch, and 14-inch plates: other vessels with from 20- to 24-inch armor are now in course of construction. The 7-inch (150-pounder) rifled gun which perforated the "Warrior," was followed by rifled guns of 8-inch (180-pounder), 9-inch (250-pounder), 10-inch (400-pounder), 11-inch (500-pounder), 12-inch (700-pounder), and 12½-inch (800-pounder). A 14-inch rifled gun (1150-pounder) has been successfully constructed by Herr Krupp; and a 16-inch rifled gun (1700-pounder), manufactured in the Royal gun-factory, is now under trial at Woolwich. Seventeen-inch guns (1900-pounders) are in course of construction at Elswick by Sir William Armstrong & Co.* It is, moreover, apparent that this battle between the attack and defense has assumed the character of a gigantic international duel.

The problem demands, and receives, the most careful consideration of the scientific artillerist and the mechanical engineer, while some of the greatest achievements of the forge-master are required in attempting its solution. All the mystery which may have previously existed in matters of gunnery has now been cleared away; and the general principles upon which trustworthy guns can be constructed are perfectly well known and understood. It is, therefore, only in details that we may expect differences in the future construction of trustworthy ordnance. The precise pattern adopted by each country may—as Mr. Stuart Rendel very justly says—be "the result of compromise, and of a nice adjustment of the balance of advantage and disadvantage, as viewed by the respective ordnance authorities, and as well from a political and economical as from a technical point of view." But, however the details of metal, rifling, and method of

* One of these guns has been finished and is now under trial.

loading may differ, the main conditions upon which the power of the guns depends—namely, velocity, penetration, and accuracy—must be secured. At present the most prominent methods of constructing heavy ordnance in Europe are three in number: the English, the French, and the German.

In the English, or Woolwich muzzle-loading system, the gun is built up of a strong, solid-ended steel tube, surrounded by several double or triple wrought-iron coils. It is claimed that this method of construction produces the safest, cheapest, and simplest system of heavy ordnance. The guns are said to be the most powerful of their class, and to possess the great merit of non-liability to burst explosively,—the failure of a gun being preceded by timely warnings to the gun detachments.

The French breech-loading system of construction (modèle 1871) consists of a cast-iron tube, reinforced from the breech about one-third of its length by a steel tube, and strengthened over the breech, as far as the trunnions, by superimposed rings of puddled steel. Thus the breech of the gun, where the strength is required, is fortified by an inner steel tube and outer steel rings, and the chase is simple cast-iron, unstrengthened.

The German or Krupp breech-loading method of construction has been very fully detailed in the report on the Vienna Exhibition. It consists of a steel tube surrounded by superimposed steel rings.

It would be impossible without a practical competitive trial to form an opinion as to the relative merit of these three systems, or to decide which country has the best armor-piercing gun. It is only possible to produce figures, drawn from the most trustworthy sources at our command, and arranged in the most convenient form.

The comparative merit of armor-piercing guns is deduced on paper from the weights of the projectiles which they throw, and the velocity with which these projectiles strike the object at which they are directed. The blow thus struck is proportional to what in scientific language is termed the “energy” of the projectile at impact. The numerical value of this quantity is found by multiplying the weight of the projectile in pounds by the square of the velocity on impact in feet, and dividing the product by twice the force of gravity in feet,—or

$$E = \frac{Wv^2}{2g} \dots\dots\dots (1)$$

As a matter of convenience it is usual to express the result in foot tons, and as there are 2240 pounds in a ton, equation (1) becomes

$$E_t = \frac{Wv^2}{4480g} \dots\dots\dots (2)$$

Here E , equals the total energy of the projectile, on impact, in foot tons; W equals the weight of the projectile, in pounds; and v equals the velocity of the projectile, upon impact, in feet. The facility with which the projectile will perforate an armored structure depends upon its diameter as well as upon its energy; but scientific artillerymen are not agreed upon the expression which most faithfully represents the comparative powers of different diameters. As an illustration, however, we shall select the English expression, which assumes that the resistance offered by armor varies as the calibre. It is usual to express this rule by introducing into the formula the shot's circumference in inches, and to call the result of the computation the "energy per inch of the shot's circumference."

Thus, if E , be the total energy and E_{II} , the energy per inch of the shot's circumference:

$$E_{II} = \frac{E}{\pi D} = \frac{Wv^2}{4480 g \pi D} \dots\dots\dots (3)$$

where D is the diameter of the projectile in inches.

The following table gives the principal dimensions and weights of English, French, and German armor-piercing guns, and a comparison of their relative merit as indicated by equation (2):

THE ENGLISH, FRENCH, AND GERMAN SYSTEMS OF HEAVY ORDNANCE, 1876.

PARTICULARS.	ENGLISH.			FRENCH.			GERMAN.		
	12 5-IN.	11-IN.	10-IN.	12.5-IN.	11-IN.	9.5-IN.	11-IN.	10-IN.	9-IN.
GUN.									
Calibre, inches.....	12.5	11	10	12.6	10.8	9.5	11.02	10.24	9.27
Length of bore, inches.....	198	145	145.5	204.1	163.7	162.6	207.1	194.5	177.6
Total weight, tons.....	38	25	18	34.5	21.7	13.8	27.07	21.65	15.26
COMMON SHELL.									
Weight empty, pounds.....	668	501.25	374	593.5	303.8	211.25	381	330.7	247
Diameter, inches.....	12.42	10.92	9.92	12.66	10.89	9.55	11.16	10.37	9.38
Length, inches.....	36.2	34.2	32.5	34.1	24.02	21	.....	.....	.....
Bursting charge, pounds.....	43.8	28.75	27.1	38.1	13.67	9.25	23.48	19.8	15
Total weight filled, pounds*.....	726.5	530	401.1	631.6	317.5	220.5	404.5	350.5	262
BATTERING PROJECTILE.									
Diameter, inches.....	12.42	10.92	9.92	12.66	10.89	9.55	11.16	10.37	9.38
Length, inches.....	33	28.3	26.3	.....	24.4	21	27.56	25.6	23.2
Total weight, pounds.....	815	535	400	760.5	476.4	317.6	517	414.5	306.4
BATTERING CHARGE.									
Weight, pounds.....	130	85	70	136.7	88.2	61.7	88.18	70.55	52.9
Muzzle velocity, feet.....	1,425	1,315	1,364	1,312	1,378	1,427	1,394	1,385	1,312
Total energy at muzzle, foot tons	11,160	6,415	5,160	9,080	6,270	4,480	6,970	5,515	3,660

The greatest amount of work realized in any gun to date (August 5, 1876) resulted in firing the 80-ton Woolwich gun, bored to 16

* Experiments are in progress with a common shell 815 pounds in weight and 37.5 inches long.

inches, with a charge of 350 pounds of 1.5-inch cubical powder and a projectile 1703 pounds in weight. In this case the muzzle velocity was 1505 feet, the muzzle energy 26,740 foot tons, and the mean pressure in the powder-chamber 20.4 tons on the square inch.

The question between muzzle-loading and breech-loading for heavy guns is a most complicated one, and can only be decided by balancing the advantages of one system against the other, according to the nature of the service for which the gun is required. The system of breech-loading now in use for heavy guns may be divided into two classes :

1. Those in which the breech is closed by means of a wedge or stopper introduced through an opening in the side of the gun, as in the Krupp system.

2. Those in which the closing is effected by a screw, withdrawn from the breech at every round, as in the French system.

For heavy rifled guns the points of greatest importance are strength, endurance, power, accuracy, and simplicity and safety in working. The practical question to be decided is whether these conditions can best be realized, as a whole, by inserting the charge at the breech or at the muzzle. It must be admitted that a solid-ended steel tube in the strongest part of the gun will afford greater longitudinal strength than the breech-loading arrangement in either of the above systems; but, in reply to this, it is asserted that the longitudinal strength given by the breech-loading construction is sufficient for all practical purposes, as shown by the fact that well-constructed breech-loading guns do not give way at the breech. As regards endurance a superiority is claimed for the breech-loader on the score of the vent—the most perishable part of the gun—passing through the breech-wedge or screw instead of through the body of the piece. The breech-wedge can be renewed at pleasure. It is also urged that in a *système forcé* in which lead-coated or copper-banded projectiles are employed there is less chance of erosion in the bore. These claims are met by an admission that the power of renewing at pleasure that part of the gun in which the vent is situated constitutes an advantage for breech-loading; but it is pointed out that the use of a “gas check” or expanding base-ring effectually closes the windage in the muzzle-loading guns, and thus places them on a par with breech-loaders as regards erosion of the bore.

With respect to power and accuracy, it is urged that both are increased by having a long bore, and that the breech-loading gun may be made of any desired length without practical inconvenience; whereas the length of the muzzle-loader must depend on the position in which it is mounted. In reply to this argument the advocates of

muzzle-loaders admit the advantage with respect to guns mounted in fortifications and on the broadside of vessels, but do not accept it in the case of turret-vessels armed with two guns in each turret. It is urged that the dimensions of turrets are governed by the space required for the guns' crews to work, or the space which must be left between the gun-slides and the interior of the turret; with guns of similar calibre this space would, it is said, be the same whether the guns were breech-loaders or muzzle-loaders. Simplicity and safety in working includes ease of loading, exposure of the men while loading, treatment of recoil, and the possibility of the gun being rendered unserviceable while in action.

The advocates of breech-loading urge that the labor and difficulty of bringing up a heavy projectile to the muzzle, and of placing it in the bore where the space is most confined and the men have least room to work, is considerably mitigated in the service of a breech-loader. Moreover, muzzle-loading guns necessitate long sponges and rammers, and the manipulation of such long staves is attended with much difficulty and loss of time. These difficulties also naturally increase with the length of bore and weight of projectile, so that every advance in the size of guns favors the breech-loading system. In consideration, therefore, of the reduced distance over which the charge has to be carried, and the facility afforded in ramming it home, a greater rapidity of fire is claimed for breech-loaders.

It is urged that with muzzle-loaders the men are much exposed to the fire of the enemy's guns and rifles, and that their *morale* may be destroyed by the casualties caused by sharpshooters or Shrapnel shell. In the service of the muzzle-loader from six to eight men are grouped together for some considerable time in the most exposed position—*i.e.*, at the opening of the port or embrasure—whilst sponging and loading the gun. With breech-loaders the same men are at a distance from the port, and are covered to a great extent by the gun and carriage. It is said that recoil can be more easily and simply treated in breech-loaders, as the muzzle-loaders require a nice adjustment of the compression to insure sufficient recoil for loading; and, in case the recoil should not be sufficient, running-back tackle must be used, thus causing delay. It is further urged that injury to the gun whilst loading is reduced to a minimum in breech-loaders. In the hurry of action, and difficulty of handling the long, unwieldy rammer of a muzzle-loader, the projectile may not be sent home on the cartridge,—a circumstance which would not only be attended by loss of accuracy, but might lead to fatal injury being inflicted on the gun through the premature bursting or breaking up of the projectile.

The condition of the bore of the breech-loader can be ascertained at any moment, and it is sure to be kept free from dirt and rust, which, in muzzle-loaders, are difficult to detect and are detrimental to the gun. Lastly, the breech-loader, assuming the safety of the breech-action, is perfectly exempt from those distressing accidents which from time to time occur from the premature explosion of the cartridge.

In reply to these arguments* the advocates of muzzle-loaders admit that the actual manual labor expended in loading a heavy muzzle-loading gun is probably greater than in a breech-loader of the same calibre, and that this increases with the size of the gun, but they point out that, as a matter of fact, no real difficulty is experienced in loading heavy muzzle-loading guns up to the 12-inch, and that the introduction of machinery will supersede manual labor in guns of the heaviest nature. It is as easy, if not easier, to apply machinery for this purpose to a muzzle-loader as to a breech-loader.

It should, moreover, be borne in mind that the time saved in the breech-loader by the reduced distance over which the charge must be carried, and the facility afforded in ramming it home, will be counterbalanced by the time lost in opening and closing the breech and inserting and withdrawing the bridge. Indeed, there is no clear proof that, with the heavy rifled guns now actually used by European powers, breech-loaders have any advantage in rapidity of fire over muzzle-loaders.†

With respect to the exposure of the detachments while loading muzzle-loaders, it is pointed out that the assumption cannot be admitted as regards guns mounted in armor-clad vessels, because the ports are always fitted with iron rifle-proof lids having a small circular

* Many of the following arguments are condensed from an excellent paper on the subject by a distinguished British naval officer.

† The following facts are interesting as instances of the rapidity of fire of heavy muzzle-loading rifled guns. The English ironclads "Monarch" (turret) and "Hercules" (broad-side), when steaming at the rate of between four and five miles an hour, opened fire at a rock distant about one thousand yards, using battering charges and Palliser projectiles.

The "Monarch" in five minutes fired twelve rounds from the four 12-inch guns, and struck the rock seven times. The "Hercules" in five minutes fired seventeen rounds from her four 10-inch guns, and struck the rock eleven times. In June, 1876, some practice was carried out at Shoeburyness, in England, to test the rapidity of fire and accuracy of the 12.5-inch rifled gun, of thirty-eight tons, firing 800-pound projectiles with 130-pound charges. The gun was directed successively at three targets, at the respective distances of one thousand, one thousand five hundred, and two thousand yards, each target being taken in turn, so as to vary the direction and training of the guns for each round. The average time of firing was two minutes and twenty seconds per round, and the practice was excellent, all the targets being completely shot away.

hole in the centre through which the handles of the sponge and rammer are worked, and these port-lids are lowered whilst the guns are being loaded under rifle or Shrapnel fire. The same system could probably be applied to the embrasures or shields of casemated works.

No practical difficulty is said to be found in controlling the recoil of muzzle-loading guns, and with a little practice the compression can be adjusted so as to allow the gun, on recoil, to assume the proper position for loading without using the running-in gear at all; but in the event of the gun not having recoiled sufficiently, owing to too great compression having been given, a very few turns of the running-in winches places it immediately in the required position. The possibility of injury being caused to the gun by careless loading in the muzzle-loader is counterbalanced by the possibility of careless manipulation of the breech-closing apparatus of the breech-loader. But, in order to insure the projectile being rammed close to the cartridge, a plain and distinct mark is placed on the staff of each rammer in such a position that when the mark is in line with the muzzle of the gun it is certain that the projectile is close home on the cartridge. There is no case on record of the premature explosion of a cartridge while firing shotted charges in a heavy muzzle-loading rifle gun, and the practice of using saluting charges in such guns, although attended with very little risk, should be discouraged as much as possible.

Lastly, the advocates of muzzle-loading lay considerable stress on the simple character of the weapon. It is urged that in actual warfare we require an article with the *minimum* chances of going out of order. There is always a chance that the breech-closing arrangement may give trouble just at the most critical moment, whereas comparatively nothing can go wrong in a muzzle-loader. The foregoing are the main arguments on the question of breech- *versus* muzzle-loading for armor-piercing guns.

To give an opinion one way or the other is not within the scope of this paper; indeed, the duty of the "expert" lies in placing the arguments impartially side by side, so that in discussing the question the true advantages and disadvantages may be clearly recognized. The subject can then be dealt with, not as a question of sentiment, but as a matter of fact.

The subject of gunpowder will be treated under the head of Explosives; but as the development of modern ordnance has, in great measure, depended upon the invention of large-grained gunpowder by General Rodman and the subsequent improvements in manufacture, it will not be out of place to give a brief *résumé* here of the general

conclusion which may be drawn from recent experimental research in this direction.

1. It has always been a matter of difficulty to distinguish a "blow" from a "pressure." A blow is said to be a pressure suddenly applied; but as there must always be variation in the suddenness of application, we cannot easily define the point where the pressure ends and the blow begins.

It has long been assumed that the effect produced by the explosion of a charge of gunpowder within the bore of a gun partakes of the character of a blow, but recent experiments appear to indicate that this is not the case. In the investigations carried out at Woolwich in 1869-76, the pressure was directly recorded by means of an instrument on the Rodman principle. The apparatus, termed the "Crusher-Gauge," is screwed into the body of the gun, and admits of the explosion acting directly on the base of a small steel piston, which, in its turn, acts upon a small cylinder of pure copper. The latter, on the explosion of the charge, is compressed by the piston, and the amount of compression is a measure of the pressure exerted. It has been found that successive applications of pressure produced by again and again using the same copper cylinder with similar charges, produce no further compression over that due to the first charge than might be accounted for by variation in the pressure of similar charges.

For example, in a 10-inch gun the effect of firing a 400-pound projectile with a 70-pound charge of pebble-powder was to reduce the length of the copper cylinder, say from 0.5 inch to 0.25 inch; but this cylinder was not perceptibly reduced in length lower than 0.25 inch, by subjecting it to the action of several other discharges of 70-pound charges and 400-pound shot. A similar copper cylinder was then placed under a falling weight and made to receive a blow which reduced its length from 0.5 inch to 0.25 inch. It was then subjected to several successive blows given by the weight falling again and again from the same height. The result was that it was battered into a form somewhat resembling a cent. It is evident, therefore, that the pressure produced by slow-burning powder is not dynamical, or similar to that due to a weight falling from a height.

The following table gives the results of an experiment in which the same cylinders were subjected several times to the action of heavy charges fired from a 12½-inch rifled gun of thirty-eight tons. In some cases the form was unchanged after the second round.

PRESSURES INDICATED BY THE CRUSHER-GAUGE IN THE 12.5-INCH
RIFLED M. L. GUN.

Charge 130 pounds of 1.5 inch cubical powder. Projectile 800 pounds.

NO. OF ROUND.	MUZZLE VELOCITY.	PRESSURE IN TONS PER SQUARE INCH AT VARIOUS POINTS FROM END OF BORE.						REMARKS.
		0	12 inches.	24 inches.	36 inches.	48 inches.	60 inches.	
1	1401	22.3	21.4	20.3	20.1	14.1	12.0	New copper cylinder.
2	1417	22.7	22.8	20.4	21.1	14.9	12.1	Same coppers as used in round 1.
3	1408	22.7	22.9	20.5	21.3	16.1	12.3	Same coppers as used in rounds 1 and 2.
4	1424	22.7	22.9	22.4	23.6	17.1	12.7	Same coppers as used in rounds 1, 2, and 3.

These experiments corroborate those made previously on the same subject by General Rodman.

2. The use of unsuitable descriptions of powder, or even of excessive charges of slow-burning powder, may give rise to oscillations of pressure termed "wave action," which act violently on local points in the powder-chamber without contributing to the useful effect of the charge.

3. If powder be burned uniformly in the gun without indication of wave action, the pressure will increase with the increase of charge,—at first very rapidly, but after twenty tons on the square inch has been exceeded, then very slowly.

4. With a suitable charge for the gun, the pressure in the powder-chamber increases slowly but steadily with the increase in weight of the projectile up to a certain point: beyond this point no material increase of pressure can be obtained by increasing the weight of the projectile.

5. As already stated, the greatest amount of work heretofore realized in any gun resulted in firing the 80-ton Woolwich rifled muzzle-loading gun with a charge of 350 pounds and a projectile 1703 pounds in weight. In this case the muzzle velocity was 1505 feet, total muzzle energy 26,740 foot tons, and mean pressure in the powder-chamber 20.4 tons on the square inch.

The Krupp 14-inch breech-loading rifled gun has realized a muzzle energy of 21,300 foot tons in firing a charge of 297.6 pounds, and shot of 1146.4 pounds, the pressure being 25.9 tons on the square inch.

6. Experiment has shown that the pressure produced by the explosion of large charges can be varied and controlled by mechanical alterations in the form and density of the gunpowder used. It has also been proved that hydraulic power can be easily applied to the service of the heaviest guns. We may, therefore, conclude that the size of heavy rifled ordnance will go on steadily increasing, and will only be limited by practical requirements.

MACHINE-GUNS.

The machine-gun, although of comparatively recent date as a weapon of practical use in military operations, cannot be regarded as a new invention, or even as a novel idea in the science of mechanism. At no period in the history of firearms did the genius of invention rest content with the completion and successful trial of any single weapon; for no sooner was such success assured than mechanical ingenuity seized upon the idea, and endeavored by all manner of strange devices to increase and multiply the destructive effect of the newly-discovered power. This constant effort to combine in one weapon the force of many kept pace with and adapted to its own use the discovery of each new principle in the development of firearms; so that the history of machine-guns may be said to have commenced with the crude matchlocks of olden times, and to have continued uninterruptedly to the perfection of the modern breech-loader.

Machine-guns, under the names of *ribaudequins orgues*, organ- or tube-guns, were known in the early days of artillery,—a gun composed of four breech-loading tubes of small calibre placed on a two-wheeled cart having been used in Flanders as early as 1347. Mention is also made of a machine, used in Italy in the fourteenth century, which consisted of a carriage having one hundred and forty-four small bombards ranged upon it, in rows of twelve each, so that thirty-six balls could be fired at once. Four-tubed guns were also used by the Scotch during the civil war in 1644.

All of these guns were of a clumsy construction, uncertain in range, and so slow in delivering their fire that they were regarded as of very little value; and although much improved during the sixteenth and seventeenth centuries, they were gradually superseded by the introduction of field-artillery, which until that time had not been in actual use, owing to the difficulty of constructing carriages strong enough to resist the recoil of the guns and at the same time possessed of the lightness and mobility requisite for a field-piece.

Little more is heard of machine-guns during the two centuries following, until the Crimean War woke up the spirit of destructive invention. Among the hundreds of warlike implements which immediately appeared were several varieties of compound guns mounted on frames and wheels, and loaded and fired by various complex devices.

None of these inventions, however, were considered suitable for active service; but as they undoubtedly possessed some of the essential features of a perfect machine-gun, the interest in them was not allowed to subside. The War of the Rebellion in America following

soon after, aroused all the inventive genius of the New World, gave additional impetus to European attempts, and in a few years brought machine-guns so near perfection that their successful use in active service during the Franco-Prussian War demonstrated the fact that the difficulties which had so long prevented their adoption had finally been overcome, and that a new weapon had taken its place in modern warfare. The history of these arms in the United States, beginning with an 11-barreled breech-loading gun introduced during the War of 1812, and ending with the Gatling gun of world-wide reputation, shows a continuous series of attempts to solve the difficult problem of combining magnitude of effect with simplicity of mechanism. The records of the Ordnance Bureau of the War Department alone contain descriptions of no less than twenty-five different designs of machine-guns, and these probably form but a small portion of the number actually invented. They include almost every possible method of arranging the barrels, and in the operations of loading and firing call into use all the means of effecting that purpose which from time to time have been introduced into the manufacture of small-arms. They were used for the first time, though to a very limited extent, during the Rebellion,—a Requa rifle-battery used at the siege of Charleston being almost the only instance on record. Other varieties, such as the Union or "Coffee-mill" gun, the Rapheal repeating-gun, the Kellogg gun, and the Vandenburg volley-gun, were brought into notice from time to time and were tested by the Government, but none were found suitable for active service. All of these machine-guns had the same objectionable features that had prevented the adoption of their numerous predecessors, viz., complexity of mechanism, want of mobility necessary in field-artillery, and damaging recoil from the simultaneous explosion of so many distinct charges of powder.

The Gatling gun, invented in 1862 and subsequently much improved, was a long step in advance of all the machine-guns that had preceded it, and possessed to a great extent that simplicity and lightness so much needed in an arm of this kind. It was not until January, 1865, however, that its merits were brought to the knowledge of the War Department, and extensive and elaborate trials were inaugurated, which finally resulted in its adoption into the military service of the United States. The early history of the Gatling, like that of all breech-loaders, is clouded by defects and failures arising from the want of the essential feature of this system, viz., an effectual gas check; this was at length furnished by the adoption of a metallic cartridge for all breech-loading arms,—so that, after all, it owes a great part of its

success to the perfection of late attained in the manufacture of this ammunition.

EXPLOSIVE AND FULMINATING COMPOUNDS.

During the past century a great advance has been made in knowledge respecting the nature of explosive agents, and many new varieties have been added to the list available for use in peace and in war. Indeed, one hundred years ago gunpowder was exclusively employed, while to-day it is often superseded by more powerful and economical agents then quite unknown. Although, from obvious reasons, this class could only be represented by imitations at the Centennial Exhibition, the subject is one of so much importance that a few words respecting the explosives now in common use will not be out of place.

The effects of an explosion are due to the sudden evolution of a great volume of highly-heated gas in a confined space. Detonation implies that this physical change occurs instantaneously, giving rise to a violent blow rather than to a sustained pressure. The essential constituents of most explosives are carbon, oxygen, and nitrogen; and the gaseous products consist mainly of carbonic acid gas and free nitrogen, but other elements are often present and enter into the chemical reactions.

Modern explosive agents may be divided into two great classes, mechanical mixtures and chemical compounds. To the former belong the nitrates and chlorates, and to the latter gun-cotton, nitro-glycerine and its compounds, the picrates, and the various fulminates, each of which will be briefly considered in turn.

The Nitrates.—Gunpowder is the best-known type of this class. It is a mechanical mixture of potassium nitrate, carbon, and sulphur, the proportions by the atomic theory being about 74.5, 13.5, and 12.0 respectively. For the military service the proportions usually differ but slightly from these figures; for sporting purposes the potassium nitrate is often increased, and for blasting purposes decreased. The general characteristics of gunpowder and the usual process of manufacture are too well known to require notice here; but a very recent modification in the latter, invented and introduced in Russia by Colonel Wierner three years ago, merits attention,—especially as samples of the powder thus made have been submitted to the Judges of Group XVI.

The new process consists, essentially, in replacing the wetting, compressing, and drying processes by dry hot pressure between steam-heated plates. The temperature should be about 248 Fah. A pressure of 30 atmospheres gives a density from 1.66 to 1.70, and of

130 atmospheres from 1.86 to 1.90. The powder should remain under pressure for ten minutes. It is claimed that by this change the needful machinery and the cost of production are largely reduced; that the powder is rendered less absorbent; that the operation is less dangerous, because from the great saving of time less bulk is operated upon at once; and, lastly, that greater uniformity in density is secured. After soaking samples of the powder shown at this Exhibition for ten days in pure water the plates did not break up, while powder of excellent quality made in the usual way, treated in like manner, soon became thoroughly disintegrated. The process can be used as well for blasting powder made from sodium nitrate as for the higher grades made from potassium nitrate.

Although gunpowder has been in general use for more than five hundred years, the modern system of experimental research has led to great advances in knowledge respecting it during the past century. The investigations of Count Rumford, communicated to the Royal Society in 1797, furnished data respecting the pressure developed by its explosion, which have continued to be regarded as the best standard until very recently (1875), when the elaborate results obtained by Captain Andrew Noble and Mr. Abel were published. In 1825, Chevreul drew attention to the difference in decomposition caused by variations in the conditions under which gunpowder may be exploded. General Piobert made many valuable experiments between the years 1831 and 1836, which were fully elaborated in his standard work published in 1859. In 1841, Colonel Rumford, U. S. A., devised a system of measuring the pressure exerted in different parts of the bore of a cannon, which has done much to improve the construction of modern ordnance. In 1856, General Rodman, U. S. A., invented better apparatus for observing these pressures, and by its aid discovered the important and normal changes which may be caused in the ratio between the pressure exerted upon the gun and the velocity communicated to the projectile by judiciously varying the size and composition of the grains. These studies led him to invent mammoth and perforated cake powder, which have been adopted, with certain modifications, by the British Government under the names of pellet and pebble powder, and by the Russians under the name of prismatic powder. Without these inventions the immense guns now adopted in all military services could never have been introduced. The general principle upon which these improvements are based is the fact that gunpowder does not detonate, but burns; and that the rate of burning may be varied by changing the size and form of the grains, and by regulating their density and hardness and the mechanical condition of their

exterior. For instance, the powders employed in the experiments in progress with the 80-ton gun in England consist of grains of a cubical form varying from one to two inches on the edge.

Space forbids even an enumeration of the works upon gunpowder which have appeared during the past twenty years; but the following summary of some of the more important conclusions announced by Noble and Abel will give a sufficient idea of the present state of knowledge upon the subject.

When gunpowder is fired in a space entirely confined, one gramme occupying one cubic centimetre, the products consist of about fifty-seven per cent. by weight of matter, which ultimately assumes a solid form, and forty-three per cent. of permanent gases,—of both of which chemical analyses are given by the writers. At the instant of explosion these fluid and gaseous products are approximately of the same specific gravity. The tension is about 6400 atmospheres, or about forty-two tons per square inch, if the powder entirely fills the space in which it is fired. The temperature of explosion is about 4000° Fah., and about 705 gramme units of heat are developed by the decomposition of one gramme of the kind of powder tested.

When gunpowder is fired in the bore of a gun the proportions of the solid and gaseous products are the same as the above. The work on the projectile is effected by the elastic force due to the permanent gases. The reduction of temperature due to the expansion of the permanent gases is in a great measure compensated by the heat stored up in the liquid residue. The total theoretical work of gunpowder, indefinitely expanded, is about 486 foot tons per pound of powder. For many other important details and formulæ, reference should be made to the original paper which appeared in the *Philosophical Transactions of the Royal Society*, 1875.

The cost of potassium nitrate has occasioned many experiments to be made with a view to replacing it by other nitrates, especially with that of sodium; but the deliquescent character of that salt is so objectionable that, although it is largely employed in making blasting powder, it is little used for the other varieties. By substituting uncarbonized peat in place of part of the carbon, Mr. Oliver has lately succeeded in making a powder which, when well rammed, is claimed to give a high initial velocity with less recoil and smoke than ordinary grades of cheap powder. Kellow's powder was prepared several years ago from potassium nitrate, spent tan, and a little sulphur; and a similar blasting powder, under the name of pudrolythe, has recently appeared in England. The latter is said from its slow rate of burning to have great lifting force in quarrying.

The Chlorates.—Potassium chlorate gives up its oxygen much more readily than potassium nitrate, and when mixed with carbon in various forms makes a powder which explodes more sharply than gunpowder, and, indeed, resembles the chemical compounds in the suddenness and violence of its action. It was introduced and considerably used in blasting in this country a few years ago, but its extreme sensitiveness to friction led to many accidents, and it is now practically superseded by the nitro-glycerine mixtures. The principal forms were known as Horsley's powder, Oriental Safety compound, White gunpowder, and Erhardt's powder; composed, respectively, by mixing potassium chlorate with nut-galls, crude gamboge, potassium ferrocyanide, and tannin. If sulphur be used in combination with the oxidizing agent an extremely dangerous mixture is formed, which, however, finds a special use as a priming for explosive bullets.

By using potassium chlorate as an absorbent for combustible liquids many of the objections to this class are removed, for the two portions may be kept separate, and only united as desired for use. Moreover, the incorporation, which with the carbon in a solid form is very dangerous, is rendered safe. A mixture of potassium chlorate and petroleum belongs to this type; but a very powerful detonator, like a disk of gun-cotton, is needful to effect explosion.

Gun-cotton.—The history of gun-cotton is peculiarly interesting, and well illustrates the advantage of thorough experimental investigation in dealing with explosives. The germ of the discovery dates from 1832, when Braconnet ascertained that by dissolving starch in nitric acid and adding water a white explosive solid was precipitated, to which the name xyloidin was given. Shortly after pyroxylin was discovered by Pelouse in treating paper and cotton or linen cloth with nitric acid. Gun-cotton was first made by Schönbein in 1846, and at once attracted general notice as a possible substitute for gunpowder in the military service. Commissioners were appointed by several governments to investigate its properties; but in every country except Austria adverse reports were made, based on its supposed liability to spontaneous explosion, its violent and irregular action, and its corroding residua. Baron von Lenk of the Austrian commission alone continued the study, and made an elaborate series of experiments, which promised so well that, in 1853, he constructed a 12-pounder field-battery which was temporarily introduced into the Austrian service. His improvements consisted in more thoroughly purifying the ingredients, in devoting special attention to removing all traces of acid from the finished product, in rinsing it in a hot

solution of potassium silicate to retard combustion, and in regulating the density by weaving it into cloth, or twisting it into ropes, to secure uniformity of action. This Austrian success led the British War Office to renew experiments; and, beginning his investigations in 1863, Mr. Abel has succeeded in so greatly improving the manufacture that gun-cotton is now recognized as the safest known explosive. Although not suited for use in artillery, it has been adopted by many nations for the torpedo service, and is very largely used for blasting purposes. Abel's principal improvements consist in thoroughly pulping the gun-cotton after its treatment with the mixed acids and moulding it into disks which are strongly compressed by applying pressure ranging from four to six tons per square inch. He employs ordinary cotton-waste, instead of the expensive long staple variety adopted by Lenk; and his pulping process effectually removes all free acid, which could not certainly be done in the Austrian method of manufacture. The recent discovery that even wet gun-cotton can be detonated by exploding a dry disk in contact with it, while it is absolutely safe against ordinary accidents, has largely added to the value of this new explosive. If frozen, however, it recovers its liability to detonation. It is reported that works will soon be established in the United States, under the Abel patent, with a view to introducing gun-cotton into general use here.

The chemical formula of gun-cotton is $C_6H_7N_3O_{11}$. Ignited (in the form of disks) in small quantities and unconfined it burns with a strong blaze. Fired by a detonating fuse, or raised to a temperature of about 350° Fah. in a stout case, it explodes with great violence. Very recently attempts have been made to furnish the slightly deficient supply of oxygen by soaking in a solution of potassium nitrate or chlorate, and experiments in this direction, as well as the manufacture in a granulated form, mark the latest stages of progress.

In practice, the detonation of all modern explosives is usually effected by the use of small initial charges of fulminates, and some very surprising facts have recently been established which go far to induce a belief that synchronism in vibration is an important element. Thus, compressed gun-cotton may be detonated by five grains of fulminating mercury, but requires fifty grains of chloride of nitrogen, and fails with one hundred grains of iodide of nitrogen, and even with one hundred and twenty-four grains of nitro-glycerine itself, which develops far more heat and mechanical force. On the other hand, a small initial charge of gun-cotton readily detonates nitro-glycerine. Fulminating mercury is usually adopted in practice for this use, to which it appears to be especially suited.

Mr. Abel has recently determined the velocity of detonation, transmitted from disk to disk of dry gun-cotton in contact, to be about seventeen thousand feet per second, while if the disks are saturated with water it is decidedly higher,—say twenty thousand feet.

Nitro-glycerine.—This explosive was discovered in 1847 by As-cagne Sobrero, but was first introduced into general use in blasting by Alfred Nobel in 1864. Since that date it has been largely employed in Europe and this country. It is the most powerful agent now known; but, uncombined with absorbents, it is justly considered as dangerous in manipulation and as unfit for long storage on account of liability to spontaneous decomposition, or even detonation, unless extreme care has been observed in its manufacture.

It is made by slowly introducing pure glycerine into a mixture of strong nitric and sulphuric acids, especial attention being paid to preventing a rise of temperature. There are believed to be three nitro-glycerines, mono-, di-, and tri-; and the chemical formula of the latter, which should be as exclusively produced as possible, is $C_3H_5N_3O_9$. Above 40° Fah. it is an oily liquid having a specific gravity of 1.6, odorless, and of a sweet taste. It is poisonous; and, if placed in contact with the skin, even in small quantities, before the system has become accustomed to its action, it produces violent headache. Below 40° Fah. it congeals into a white crystalline solid, which is nearly or quite unexplosive, and which may be handled or transported with safety. It may readily be thawed by introducing the can into warm water, which restores its full explosive power. These characteristics are those of tri-nitro-glycerine. Important discrepancies reported in its properties are believed to be caused by various admixtures of the lower nitro-glycerines.

Nitro-glycerine, ignited in small quantities by a flame and unconfined, burns with difficulty like an ordinary oil. At 423° Fah. it deflagrates violently. If ignited confined, or if subjected to the explosion of fifteen grains of fulminating mercury, it detonates with tremendous force. Fully exploded, it gives off no injurious gases,—an important advantage in tunnel blasting.

The accidents which attended the use of nitro-glycerine in its liquid form led Alfred Nobel to experiments with absorbents; and, in 1866-67, he invented and introduced the explosive known as dynamite or giant powder. This consists of seventy-five per cent. of nitro-glycerine and twenty-five per cent. of an inert silicious earth. The best variety of the latter is that known as kieselguhr, found in Hanover, but many others have been employed. Nitro-glycerine in this form possesses great advantages. It is less liable to accidental

detonation from shocks and to spontaneous combustion than in the liquid state; it is more convenient to handle; frozen in the state of loose powder, it does not lose the property of exploding from the action of the usual fuse (fifteen grains of fulminating mercury), while, if compressed into cartridges, it becomes as inexplusive as nitro-glycerine itself; saturated with water, it retains its detonating power, but requires a larger initial explosion to develop it; ignited in small quantities by a flame, and unconfined, it burns quietly.

As already stated, many other absorbents beside kieselguhr have been used. They belong to two distinct classes,—those which in themselves are explosive, and those which are inert. To the former belong gun-cotton, the product being glyoxiline, saw-dust treated with nitric and sulphuric acids, the product being dualin, some modification of the elements of gunpowder, the product being variously known as lithofracteur, rendrock, vulcan powder, dynamite No. 2, giant powder No. 2, etc. Among the inert absorbents may be named Boghead coal-ashes, mica scales, artificially deposited silica, etc.

While it will generally be admitted that the detonating force of these compounds is derived solely from the nitro-glycerine contained in them, the percentage of which varies greatly owing to differences in their power of absorption, it is far from true that their economic value as explosives can be thus compared. The element of time, which determines whether a blow or a push is delivered, is of primary importance, and should practically determine which compound should be selected. In flint-rock no explosive can compete in force with liquid nitro-glycerine; but for common earth, gunpowder is far more effective. Between these limits most of the nitro-glycerine compounds named above may find a use.

The Picrates.—Picric acid was discovered in 1788 by Haussman, when treating indigo with concentrated nitric acid; but it is now often derived from other substances, especially from carbolic acid. It is used in commerce as a dye, being of a brilliant yellow color and unexplosive. Its salts are numerous, and are more or less explosive; the potassium and ammonium salts, often in connection with potassium nitrate or chlorate, are those usually employed for that purpose. Potassium picrate possesses great explosive energy, but is dangerous to handle from its liability to explode by friction. Designolle's powder, a mixture of potassium picrate and nitrate, sometimes with a little charcoal added, was formerly considerably used in France, but has ceased to be manufactured since the occurrence of a destructive accident.

Brugiere powder, a mixture of ammonium picrate and potassium

nitrate, is widely different in its properties, being safe against friction, and slower in action. Abel has recently proposed to use it in shells, under the name picric powder, and Hill is experimenting with it as a possible substitute for gunpowder in spar torpedoes.

The Fulminates.—The salts of fulminic acid are easily exploded, and some of them are dangerously sensitive to friction, electricity, etc. They are never used in large quantities, not only because of the great danger of handling them, but also because the volume of gas given off is small, thus limiting the range of effect. Fulminating mercury ($C_2HgN_2O_2$) is the only one of them which at the present time has much practical value; it is largely used in fuses, percussion-caps, primers, etc. When wet it is unexplosive, and for security it should always be kept and handled in that state.

REPORTS ON AWARDS.

GROUP XVI.

1. Smith & Wesson, Springfield, Mass., U. S.

SMITH & WESSON REVOLVING PISTOLS.

Report.—Commended for its capacity as a military arm. The ejection of all the discharged shells simultaneously, the workmanship and materials used in its manufacture, its interchangeability, and the simplicity of its action, render it a desirable weapon for defense or offense.

2. Merwin, Hulbert, & Co., New York, N. Y., U. S.

POCKET REVOLVERS.

Report.—Commended for general excellence of workmanship and beauty of finish.

3. Bayet Brothers, Liège, Belgium.

REVOLVER, SELF-ACTING COCK.

Report.—Commended for its remarkable self-acting extractor that allows the cartridges to be extracted successively, only using the right hand, which is an advantage for cavalry; and also for the simplicity and solidity of the mechanism.

4. Colt's Patent Fire Arms Manufacturing Co., Hartford, Conn., U. S.

COLT'S REVOLVER.

Report.—A military weapon extracting the discharged shells singly; combining strength and simplicity of action; not liable to get out of order; readily taken apart and easily cleaned; having entire interchangeability of parts, with a high order of finish. Commended for durability and actual service in the hands of a soldier, and for the perfection to which the manufacture of pocket pistols has been brought, and the low price at which a good arm can be produced.

5. Clark & Snider, Baltimore, Md., U. S.

BREECH-LOADING SPORTING GUNS.

Report.—Commended for good material and workmanship, improved compensating action, and improved rebounding locks.

6. E. Remington & Sons, Ilion, N. Y., U. S.

BREECH-LOADING SPORTING GUNS AND TARGET RIFLES.

Report.—Commended as good and serviceable, and at low prices.

7. Chas. Parker, Meriden, Conn., U. S.

BREECH-LOADING SPORTING GUNS.

Report.—Commended for good materials and workmanship, as shown in low-priced guns.

8. J. Stevens & Co., Chicopee Falls, Mass., U. S.

BREECH-LOADING SPORTING GUNS.

Report.—Commended as good and strong, and at very low prices.

9. P. Webley & Son, Birmingham, England.

SWINBURN'S BREECH-LOADING MUSKET.

Report.—Commended as a good breech-loading musket, regarding the solidity of the mechanism and the disposition of the different pieces.

10. John Krider, Philadelphia, Pa., U. S.

BREECH-LOADING SPORTING GUNS.

Report.—Commended for good materials, workmanship, and low prices.

11. Alexander Henry, Edinburgh, Scotland.

BREECH-LOADING RIFLE.

Report.—Commended for the perfection and simplicity of its mechanism; and the highly efficient character of the rifling, charge, and bullet, known under the name of the "Henry system."

12. P. Webley & Son, Birmingham, England.

BREECH-LOADING SPORTING ARMS.

Report.—Commended for good materials and workmanship in guns at low prices.

13. Moraes Ancora, Rio de Janeiro, Brazil.

BREECH-LOADING RIFLE.

Report.—An excellent breech-loading rifle, both by the workmanship and remarkable simplicity and solidity of the mechanism, and also by the efficiency of the system of extraction, and by the ingenious disposition of a piece of wood over the barrel to isolate the heat.

14. Dumoulin Lampinon, Liège, Belgium.

BREECH-LOADING SPORTING GUNS.

Report.—Commended for fine materials and workmanship at very low prices.

15. Lebeau & Co., Liège, Belgium.

BREECH-LOADING SPORTING GUNS.

Report.—Commended for excellent materials and workmanship at very low prices.

16. John Rigby & Co., Dublin, Ireland.

SPORTING GUNS AND RIFLES.

Report.—Commended for perfection of materials and workmanship; very superior long range rifle.

17. Charles Lancaster, London, England.

BREECH-LOADING SPORTING GUNS.

Report.—Commended for fine materials and unsurpassed workmanship, and especially for his “cast-off” stock for a person who has lost the right eye.

18. Wm. Wurfflein, Philadelphia, Pa., U. S.

PARLOR RIFLES AND TARGETS.

Report.—Commended as good, cheap, and very ingenious.

19. George Gibbs, Bristol, England.

METFORD PATENT SPORTING RIFLE.

Report.—Commended for excellence and finish in the manufacture of the Metford patent rifle.

20. William Soper, Reading, England.

LONG-RANGE SPORTING RIFLES.

Report.—Workmanship and materials good; absolute safety of action; easily and rapidly manipulated.

21. The Imperial Russian Rifle Manufactory at Toola, Russia.

RIFLES.

Report.—Commended for perfection of workmanship in the articles exhibited, particularly in the mechanism of machine-made infantry rifles, and the admirable system of gauging employed.

22. The Rifle Manufactory at Sestroretsky, near St. Petersburg, Russia.

RIFLES.

Report.—Commended for excellence of manufacture of the Cossack muskets, and admirable system of gauging.

23. Alexander Henry, Edinburgh, Scotland.

SPORTING GUNS AND RIFLES.

Report.—Commended for very best materials and workmanship, combined with moderate prices; also for his system of rifling.

24. W. & C. Scott & Son, Premier Gun Works, Birmingham, England.

SPORTING GUNS.

Report.—Commended for materials and workmanship in their medium and best qualities, their “triplex action,” and their “compensating lump.”

25. Alfred Lancaster, London, England.

SPORTING GUNS.

Report.—Commended for finest materials and perfect workmanship.

26. James Purdey, London, England.

SPORTING GUNS AND EXPRESS RIFLES.

Report.—Commended as perfect in materials and workmanship, strong and well-proved actions.

27. Evans Rifle Manufacturing Co., Mechanic Falls, Me., U. S.

EVANS MAGAZINE GUN.

Report.—Commended for novelty in the feeding arrangement and general substantial construction.

28. J. Lang & Sons, London, England.

SPORTING GUNS AND RIFLES.

Report.—Commended for simplicity, strength, and thorough workmanship of their self-cocking gun.

29. Providence Tool Co., Providence, R. I., U. S.

LONG-RANGE SPORTING RIFLE.

Report.—A long-range rifle of good materials and workmanship.

30. Providence Tool Co., Providence, R. I., U. S.

PEABODY-MARTINI RIFLE.

Report.—A military arm combining strength, simplicity, high quality of workmanship, ease of manipulation, with accuracy and rapidity of fire, using a central fire metallic cartridge, and ejecting the discharged shell unfailingly.

31. Baron Hahn, St. Petersburg, Russia.

FORTRESS MUSKET OF LARGE CALIBRE.

Report.—Commended for good manufacture and novelty of design.

32. E. Remington & Sons, Ilion, N. Y., U. S.

MILITARY FIRE-ARMS AND AMMUNITION.

Report.—Commended for general excellence of workmanship, as shown in the manufacture of military arms and ammunition.

33. Thomas W. Sparks, Philadelphia, Pa., U. S.

DROP AND MOULD SHOT.

Report.—Commended for uniformity and general good finish of the pellets.

34. Merchants' Shot Tower Co., Henry D. Harvey, President, Baltimore, Md., U. S.

DROP AND MOULD SHOT.

Report.—Commended for uniformity and general good finish of the pellets.

35. Eley Brothers, London, England.

WADDING, SHELLS, AND PERCUSSION CAPS.

Report.—Commended as perfect in materials and workmanship.

36. C. J. Stoddard, Washington, D. C., U. S.

CARTRIDGE-LOADING IMPLEMENT.

Report.—A compact and convenient article, well suited for the object intended.

37. The St. Petersburg Cartridge Manufactory, Russia.

Report.—Commended for excellence of workmanship in articles exhibited, particularly in the admirable gauges employed.

38. Winchester Repeating Arms Co., New Haven, Conn., U. S.

METALLIC CARTRIDGES FOR SMALL ARMS.

Report.—Commended for the perfection of the metallic ammunition for military purposes.

39. United States Cartridge Co., Lowell, Mass., U. S.

MILITARY CARTRIDGES.

Report.—A re-loading, solid head metallic cartridge, containing great strength and non-liability to rupture. Commended for its adaptability to re-loading, ease of extraction, and certainty of fire; waterproof; especially adapted for use in a machine gun, where a defective head or failure to extract might prove of serious consequence.

40. Union Metallic Cartridge Co., Bridgeport, Conn., U. S.

METALLIC CARTRIDGES FOR MILITARY PURPOSES, AND ESPECIALLY THE BERDAN PATENT CENTRAL FIRE CARTRIDGE.

Report.—Commended for the system of constructing the cavity in the head of the shell, the anvil in the same on which the primer is exploded being formed from the same metal from which the shell is drawn, the conical form of the anvil assisting the effect of the blow of the firing-pin when striking the cap to ignite the fulminate; the primer perfectly waterproof, and formed complete from one piece of metal, avoiding all danger from additional pieces dropping out and causing miss-fires; the whole forming a perfect and complete system for exploding centre-fire cartridges, and for rendering them completely impervious to temperature and water, and adapting them to ready reloading after firing.

41. Ch. Fusnot & Co., Cureghem, near Brussels, Belgium.

CARTRIDGES FOR MILITARY SMALL ARMS.

Report.—Commended for the perfection of the workmanship and of the material, and also for the price and large amount of the production.

42. Gevelot, Paris, France.

CARTRIDGES AND CAPS.

Report.—Commended for the variety exhibited and the excellence of manufacture.

43. South Boston Iron Co., Boston, Mass., U. S.

THREE AND ONE-HALF INCH CONDENSED BRONZE CANNON, AND TWENTY-FOUR PDR. BRONZE HOWITZER.

Report.—Commended for improved method of manufacturing bronze ordnance under the Dean patent of 1869, the merit consisting in mechanically compressing the metal outward from the bore, by forcing through it mandrels of successively increasing size until a permanent enlargement of about one-eighth of an inch has been effected, thus increasing the density, tenacity, and elasticity of the metal; also for good chill casting.

44. **Richard J. Gatling, Hartford, Conn., U. S.**

THE GATLING GUN.

Report.—Eminently entitled to recognition, not only as one of the best machine guns in existence, but also as the first really serviceable weapon of its class. A new five-barrel gun is exhibited, showing improvements over the usual pattern in respect to simplicity; the automatic spreading of the shot; the feeding arrangement; an adjustment for adapting the gun to receive metallic cartridges having rims of varying thickness; diminished weight; increased facility in extracting the locks; and, generally, in separating the gun for cleaning, etc.

45. **The St. Petersburg Arsenal, Russia.**

Report.—Commended for excellence of workmanship in the articles exhibited, particularly in the new pattern 3.42 inch bronze breech-loading rifled gun, and in the harness for the mountain gun.

46. **The Government of Brazil.—The Rio Janeiro Army Arsenal.**

Report.—An interesting exhibit of artillery and small arms used in the Brazilian service.

47. **Fried. Krupp, Essen, Germany.**

HEAVY ORDNANCE AND LIGHT ARTILLERY.

Report.—Commended for perfection of workmanship and finish. The exhibit made by Mr. Krupp is one of the finest displays of ordnance in the Exhibition, and reflects great credit on the exhibitor.

48. **South Boston Iron Co., Boston, Mass., U. S.**

BUTLER PROJECTILES AND FIFTEEN-INCH CLUSTER SHOT.

Report.—Commended for excellence of manufacture and accuracy of finish.

49. **M. Carl Ekman, Finspong, Sweden.**

CHILLED PROJECTILES FOR HEAVY RIFLED GUNS.

Report.—Commended for excellence of quality.

50. **A. De Maré, Ankarsrum, Sweden.**

CHILLED PROJECTILES FOR HEAVY RIFLED GUNS.

Report.—Commended for excellence of quality.

51. **The Perm Gun Foundry, Russia.**

TRUNNION BARRELS AND STEEL GUNS.

Report.—Commended for excellence of manufacture of large trunnion bands, and of an experimental four-pounder steel gun, and for interesting models of twenty-inch and nine-inch guns.

52. **The Ministry of the Navy.—The Obookhof Steel Foundry, near St. Petersburg, Russia.**

HEAVY BREECH-LOADING ORDNANCE.

Report.—Fine samples of heavy breech-loading ordnance, the largest being a nine-inch gun.

53. Ordnance Department, St. Petersburg, Russia.

Report.—Commended for excellence of workmanship in articles exhibited; particularly an iron carriage for six-inch mortar on the system of Major General Semenov, and a field iron carriage with cork buffer on the system of Colonel Engelhardt, of the Russian artillery.

54. Motala Machine Co., Motala, Sweden.

PARTS OF STEEL GUNS.

Report.—Commended for excellence of workmanship and finish.

55. Paul Koorikof, St. Petersburg, Russia.

HARNESS FOR FIELD ARTILLERY.

Report.—Commended for excellent workmanship and novelty of manufacture.

56. Vonlarlarsky, St. Petersburg, Russia.

PORTABLE TRAVELING CRANE FOR ARTILLERY USE.

Report.—Commended for efficiency, economy of labor, and simplicity of application.

57. Zlatoust Armory, Government of Orenburg, Russia.

STEEL SWORDS.

Report.—Commended for excellence.

58. William H. Horstmann & Sons, Philadelphia, Pa., U. S.

SWORDS.

Report.—Commended for elegance of finish and fabrication.

59. Eskilstuna Iron Co., Sweden.

SWORDS.

Report.—Commended for first-class workmanship and material.

60. Ames Manufacturing Co., Chicopee, Mass., U. S.

SWORDS AND SCABBARDS.

Report.—Commended for elegance and variety of finish.

61. Laffiteau & Rieger, Paris, France.

SPORTING ARMS.

Report.—Commended for elegance of finish and manufacture.

62. Sharp's Rifle Co., Bridgeport, Conn., U. S.

BREECH-LOADING HUNTING RIFLE.

Report.—Commended as simple, strong, and good.

63. Westley Richards & Co., Birmingham, England.

HAMMERLESS BREECH-LOADING SPORTING GUN.

Report.—Commended for excellence of workmanship and novelty of design.

64. Winchester Repeating Arms Co., New Haven, Conn., U. S.

MAGAZINE SPORTING RIFLE.

Report.—The best magazine rifle for sporting purposes yet produced.

65. Frank Wesson, Worcester, Mass., U. S.

BREECH-LOADING SPORTING AND POCKET TARGET RIFLES.

Report.—Commended for good materials and workmanship and low prices.

66. Laflin & Rand Powder Co., New York City, N. Y., U. S.

FRICTIONAL ELECTRIC BLASTING MACHINE AND FUSES.

Report.—A very superior frictional blasting apparatus, combining electrical power, mechanical strength, portability, and general adaptation to rough blasting. Its peculiar merits are—1st, the condenser, of which the plates are well insulated, and protected against moisture by being imbedded in soft ebonite and then vulcanized; 2d, the thorough manner in which damp air is excluded from the generator by clamped casings of vulcanized rubber and a crank stuffing-box; 3d, the convenient arrangement for firing by a simple reversal of the crank; 4th, facility in opening, thus rendering occasional cleaning, re-amalgamation, etc., possible by blasters of ordinary intelligence. Also serviceable fuses for use with the above.

67. Laflin & Rand Powder Co., New York City, N. Y., U. S.

MAGNETO-ELECTRIC BLASTING MACHINE AND FUSES.

Report.—It is a compact and serviceable blasting apparatus, acting upon the dynamo-magneto-electric principle. When a sufficiently strong magnetic field has been generated by a Siemens armature working on short circuit through its electro-magnet, the current is shunted to the external circuit containing the fuses, thus utilizing, for the needed instant, both the normal current and the extra current induced by breaking the magnet circuit. The peculiar excellence of this machine lies in the manner in which the change of circuit is effected. Instead of the usual external key, an ingenious automatic trigger is introduced, to be worked by the increase in magnetic power of the magnet. This trigger is adjustable by a spring, so that it may be set to require the whole or only a small part of the available current, thus adapting the machine for convenient use, whether many or only a single fuse be employed. The apparatus is admirably suited for use where high insulation in the lead wires cannot readily be secured. Also serviceable platinum wire fuses for use with above.

68. Toy, Bickford, & Co., Simsbury, Conn., U. S.

SAFETY FUSE FOR BLASTING.

Report.—Commended for variety and excellence of manufacture.

69. Colonel Winner, St. Petersburg, Russia.

GUNPOWDER.

Report.—Commended for novelty in the manufacture of gunpowder cakes.

70. Bickford, Smith, & Co., Tuckingmill, Cornwall, England.

SAFETY FUSES FOR BLASTING OPERATIONS.

Report.—Commended for maintaining the good qualities of a valuable agent in mining industry, which was originally introduced by the exhibitors.

71. Government of Brazil.—The Pyrotechnical Laboratory of Campinho.

FUSES AND AMMUNITION.

Report.—A fine display of fuses and small-arm ammunition.**72. The Okhta Powder Mills, near St. Petersburg, Russia.**

GUNPOWDER.

Report.—Commended for excellent quality of gunpowder manufactured at this establishment.**73. Pigou, Wilks, & Laurence, London, England.**

GUNPOWDER OF VARIOUS DESCRIPTIONS.

Report.—All the gunpowders manufactured by this firm are of excellent quality.**74. V. T. Unge, Stockholm, Sweden.**

DISTANCE WATCH FOR MILITARY USE.

Report.—Commended for portability, ingenuity, and simplicity of design.**75. L. Mairlot & P. Heuse, Fraipont, near Liège, Belgium.**

DAMASCUS GUN BARRELS.

Report.—Commended for fine materials and workmanship; very low prices.**76. E. Heuse, Lemoine, & Co., Nessonvaux, near Liège, Belgium.**

DAMASCUS GUN BARRELS.

Report.—Commended for fine materials and workmanship; very low prices.**77. Kniaze Mikhailovsky Steel Works, Government of Orenburg, Russia.**

GUN BARRELS.

Report.—Commended for excellence.**78. Government of Tunis.**

WEAPONS AND EQUIPMENTS.

Report.—A highly interesting display of antique arms, including pistols, guns, swords, and daggers; also splendid embroidered saddles and horse furniture.**79. Government of Egypt.**

WEAPONS AND EQUIPMENTS.

Report.—Commended for a fine display of weapons and richly-ornamented dromedary, horse, and donkey saddles, and equipments; more particularly for the articles exhibited from the National Museum of Cairo.

80. The Spanish Ministry of War.

Report.—For a complete exhibit from the different branches of the army :

A. The Spanish Military Engineer Department.

Report.—Commended for an interesting exhibit from the Museum of Engineers at Madrid; particularly for the beautiful models of fortifications and barracks, and for the models showing the manner of transporting a trestle bridge on mules.

B. The Museum of Artillery at Madrid.

Report.—A fine display, comprising particularly models of guns and sling carts.

C. The Manufactory at Toledo.

Report.—The excellence of the celebrated sword blades.

D. The National Bronze Foundry at Seville.

Report.—For the excellent quality of field and mountain guns.

E. The National Manufactory at Trubia.

Report.—For the excellence of the iron and steel plates.

F. The National Fire-Arms Manufactory at Oviedo.

Report.—For the merit of arms, with samples to show the different stages in their construction.

81. Government of India.

ARMS.

Report.—An interesting collection of arms, selected from the India Museum.

82. Government of the Netherlands.

WEAPONS.

Report.—Commended for the exhibit of weapons from the royal small-arm factory at Delft, and for the magnificent collection of East Indian weapons from the royal cabinet of curiosities at The Hague, and from the Royal Palace Het Loo.

83. Colony of New Zealand.

WEAPONS AND CLOTHING.

Report.—An interesting collection of aboriginal (Maori) weapons and clothing, made for the commissioners of New Zealand by Mr. R. W. Woon, R.M.

84. The Artillery Department of the Royal War Office of Sweden.

Report.—Commended for excellence of manufacture and the interesting character of the articles exhibited.

85. The Investment Department of the Royal War Office of Sweden.

Report.—Commended for excellence of manufacture and the interesting character of the articles exhibited.

86. Dinaburg Arsenal, Russia.

Report.—Beautifully constructed and interesting models of the pontoon equipage now used by the Russian army.

87. The Engineer Department of the Ministry of War, Russia.—The Main Department of Engineers.

Report.—Commended for a large and fine collection of drawings illustrative of barrack structures and permanent fortifications; for the model of a gun-shield as used in the fortress of Cronstadt; and for intrenching tools.

88. The Chief Intendency of War, Russia.

Report.—A fine exhibit of military uniforms, knapsacks, and equipments generally, and of military wagons.

89. E. I. duPont de Nemours & Co., Wilmington, Del., U. S.

GUNPOWDER.

Report.—Commended for a handsome exhibit of samples representing various granulations of gunpowder, and for fine specimens of refined saltpetre.

90. Whitney Arms Co., Whitneyville, Conn., U. S.

SPORTING RIFLES ON WHITNEY SYSTEM.

Report.—A strong, safe rifle, of good workmanship and materials.

91. United States War Department, The Ordnance Bureau, Washington, D. C., U. S.

Report.—Commended for an exceedingly interesting exhibit, covering heavy and light artillery and machine guns, now in service and under experiment, as well as many samples of historical types; for an extensive collection of projectiles for rifled and smooth bore cannon, and of fuses for the same; for a large and instructive collection of military small arms, new and old; for excellent samples of military equipments generally, and especially for machinery actually at work, showing the method of making metallic ammunition and the more important parts of the adopted Springfield rifle; also for a fine exhibit of instruments used in testing ordnance and gunpowder; also for the excellent character and quality of the articles manufactured by the Ordnance Department.

92. United States Navy Department, Bureau of Ordnance, Washington, D. C., U. S.

Report.—Commended for an extensive and interesting exhibit of the ordnance, projectiles, and small arms, and especially for the offensive torpedoes used in the naval service of the United States.

93. United States War Department, Engineers' Bureau, Washington, D. C., U. S.

Report.—Commended for a handsome exhibit, covering the defensive torpedo system, the bridge equipage, the field photographic outfit, and siege and mining tools adopted by the United States; also for a beautifully finished model showing every detail of the bridge equipage and of its transportation; also for some interesting models of depressing gun carriages, notably one invented by Brigadier-General De Russy in 1835, involving the fundamental principle of the Moncrieff system, and one devised by Major King for guns of large calibre; also for a highly interesting model showing the details of the block-houses successfully used during the late war to enable a few men to defend important railway bridges against cavalry raiding parties.

94. **United States War Department, The Signal Service, U. S. Army, Washington, D. C., U. S.**

Report.—Commended for a fine exhibit of the field outfit of this bureau, and especially for the field telegraph train.

95. **United States War Department, The Quartermaster's Bureau, Washington, D. C., U. S.**

Report.—Commended for an interesting exhibit of the articles supplied and tools employed by this department, and especially for the large collection of specimens designed to illustrate the veterinary service and horseshoeing of the army.

SIGNING JUDGES OF GROUP XVI.

The numbers annexed to the names of the Judges indicate the reports written by them respectively.

HENRY L. ABBOT, 21, 22, 27, 33, 34, 36, 37, 42, 43, 44, 45, 46, 51, 52, 53, 57, 58, 60, 61, 66, 67, 68, 71, 72, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 91, 92, 93, 94, 95.

W. H. NOBLE, 19, 31, 47, 48, 49, 50, 54, 55, 56, 59, 63, 69, 70, 73, 74.

S. C. LYFORD, 1, 2, 4, 30, 32, 38, 39, 40.

GEO. A. HAMILTON, 5, 6, 7, 8, 10, 12, 14, 15, 16, 17, 18, 20, 23, 24, 25, 26, 28, 29, 35, 62, 64, 65, 75, 76, 90.

L. F. DE SALDANHA DA GAMA, 3, 9, 11, 41.

ALPHONSE LESNE, 13.

SUPPLEMENT TO GROUP XVI.

REPORTS OF JUDGES ON APPEALS.

JUDGES.

JOHN FRITZ, Bethlehem, Pa.
EDWARD CONLEY, Cincinnati, Ohio.
CHARLES STAPLES, JR., Portland, Me.
BENJ. F. BRITTON, New York City.
H. H. SMITH, Philadelphia, Pa.

COLEMAN SELLERS, Philadelphia, Pa.
JAMES L. CLAGHORN, Philadelphia, Pa.
HENRY K. OLIVER, Salem, Mass.
M. WILKINS, Harrisburg, Oregon.
S. F. BAIRD, Washington, D. C.

1. Manuel Antonio Da Silva & Sons, Lisbon, Portugal.

LEAD SHOT.

Report.—An extensive exhibit of lead shot, from large to small sizes, of good quality.

2. Firmin & Sons, London, England.

DRESS AND SERVICE SWORDS.

Report.—Commended for excellence in fabrication and finish.

3. Capt. Edward Podmore Clark, Bath, England.

MILITARY MODEL FOR ILLUSTRATING AND TEACHING DRILL MOVEMENTS.

Report.—Commended for novelty, ingenuity, and fitness for the purpose intended.

4. Tatham & Bros., New York, N. Y., U. S.

DROP AND PRESSED LEAD SHOT.

Report.—Commended for exact uniformity in size, truly spherical form, high degree of finish, and general excellence.

5. American Arms Company, Boston, Mass., U. S.

BREECH-LOADING SPORTING GUNS AND GUN LOCKS.

Report.—Commended for great strength, simplicity, and durability; non-liability of getting loose or shaky from constant service; the positive action of the extractor; the ease and rapidity with which the barrels may be detached; construction on the interchangeable

system; excellence in fabrication; the cheapest guns as strong and durable as the higher priced ones; and for very low prices. A separate exhibit of gun locks are admirable specimens of workmanship, their details interchangeable.

SIGNING JUDGES OF SUPPLEMENT TO GROUP XVI.

The figures annexed to the names of the Judges indicate the reports written by them respectively.

CHARLES STAPLES, JR., 1, 2, 4, 5.

HENRY K. OLIVER, 3.

United States Centennial Commission.

INTERNATIONAL EXHIBITION,
1876.

REPORTS AND AWARDS

GROUP XVII.

EDITED BY
FRANCIS A. WALKER,
CHIEF OF THE BUREAU OF AWARDS.

PHILADELPHIA:
J. B. LIPPINCOTT & CO.
1877.

Entered, according to Act of Congress, in the year 1876, by the
CENTENNIAL BOARD OF FINANCE,
In the Office of the Librarian of Congress at Washington.

SYSTEM OF AWARDS

[*Extract from Circular of April 8, 1876.*]

Awards shall be based upon written reports attested by the signatures of their authors.

The Judges will be selected for their known qualifications and character, and will be experts in departments to which they will be respectively assigned. The foreign members of this body will be appointed by the Commission of each country and in conformity with the distribution and allotment to each, which will be hereafter announced. The Judges from the United States will be appointed by the Centennial Commission.

* * * * *

Reports and awards shall be based upon inherent and comparative merit. The elements of merit shall be held to include considerations relating to originality, invention, discovery, utility, quality, skill, workmanship, fitness for the purposes intended, adaptation to public wants, economy and cost.

Each report will be delivered to the Centennial Commission as soon as completed, for final award and publication.

Awards will be finally decreed by the United States Centennial Commission, in compliance with the Act of Congress, and will consist of a diploma with a uniform Bronze Medal, and a special report of the Judges on the subject of the Award.

Each exhibitor will have the right to produce and publish the report awarded to him, but the United States Centennial Commission reserves the right to publish and dispose of all reports in the manner it thinks best for public information, and also to embody and distribute the reports as records of the Exhibition.

ORGANIZATION AND DUTIES OF THE JUDGES.

[*Extract from Circular of May 1, 1876.*]

Two hundred and fifty Judges have been appointed to make such reports, one-half of whom are foreigners and one-half citizens of the United States. They have been selected for their known qualifications and character, and are presumed to be experts in the Groups to which they have been respectively assigned. The foreign members of this body have been appointed

by the Commission of each country, in conformity with the distribution and allotment to each, adopted by the United States Centennial Commission. The Judges from the United States have been appointed by the Centennial Commission.

To facilitate the examination by the Judges of the articles exhibited, they have been classified in Groups. To each of these Groups a competent number of Judges (Foreign and American) has been assigned by the United States Centennial Commission. Besides these, certain objects in the Departments of Agriculture and Horticulture, which will form temporary exhibitions, have been arranged in special Groups, and Judges will be assigned to them hereafter.

The Judges will meet for organization on May 24, at 12 M., at the Judges' Pavilion. They will enter upon the work of examination with as little delay as practicable, and will recommend awards without regard to the nationality of the exhibitor.

The Judges assigned to each Group will choose from among themselves a Chairman and a Secretary. They must keep regular minutes of their proceedings. Reports recommending awards shall be made and signed by a Judge in each Group, stating the grounds of the proposed award, and such reports shall be accepted, and the acceptance signed, by a majority of the Judges in such Group.

The reports of the Judges recommending awards based on the standards of merit referred to in the foregoing System of Awards, must be returned to the Chief of the Bureau of Awards not later than July 31, to be transmitted by him to the Centennial Commission.

Awards will be finally decreed by the United States Centennial Commission, in compliance with the Act of Congress of June 1, 1872, and will consist of a special report of the Judges on the subject of the Award, together with a Diploma and a uniform Bronze Medal.

Upon matters not submitted for competitive trial, and upon such others as may be named by the Commission, the Judges will prepare reports showing the progress made during the past hundred years.

Vacancies in the corps of Judges will be filled by the authority which made the original appointment.

No exhibitor can be a Judge in the Group in which he exhibits.

An exhibitor, who is not the manufacturer or producer of the article exhibited, shall not be entitled to an award.

The Chief of the Bureau of Awards will be the representative of the United States Centennial Commission in its relations to the Judges. Upon request, he will decide all questions which may arise during their proceedings in regard to the interpretation and application of the rules adopted by the Commission relating to awards, subject to an appeal to the Commission.

A. T. GOSHORN,
Director-General.

[*Extract from Director-General's Address to Judges, May 24, 1876.*]

“The method of initiating awards which we have adopted differs in some respects from that pursued in previous exhibitions. In place of the anonymous verdict of a jury, we have substituted the written opinion of a Judge. On this basis awards will carry the weight and guarantees due to individual personal character, ability, and attainments, and to this extent their reliability and value will be increased. It is not expected that you will shower awards indiscriminately upon the products in this vast collection. You may possibly find a large proportion in no way raised above the dead level, nor deserving of particular notice. The standard above which particular merit worthy of distinction begins is for you to determine. In this regard I have only to express the desire of the Centennial Commission, that you should do this with absolute freedom, and when you meet with a product which you consider worthy of an award, we desire you to say, in as few words as you may deem suitable, why you think so.

“This, gentlemen, is all we ask of you in the Departments of Awards. Opinions thus expressed will indicate the inherent and comparative merits, qualities, and adaptations of the products,—information which the public most desires.

“Elaborate general reports and voluminous essays, though of great value as sources of general information, give little aid in determining the reliable or intrinsic merits of particular, individual products.

“The regulations which have been published divide the work of awards into three parts:

“1st. The individual work of the Judges.

“2d. The collective work of the groups of Judges.

“3d. The final decisions of the United States Centennial Commission in conformity with the acts of Congress.

“Each award will thus pass three ordeals, which, doubtless, will be ample and satisfactory.”

GROUP XVII.

JUDGES.

AMERICAN.

THOMAS GODDARD, Boston, Mass.

B. F. MORSE, Augusta, Me.

FOREIGN.

M. GUIET, Paris, France.

WILLIAM DUFFUS, Halifax, Nova Scotia.

GROUP XVII.

CARRIAGES, VEHICLES, AND ACCESSORIES.

(*For Farm Vehicles and Railway Carriages, etc., see Department of Agriculture and Machinery.*)

CLASS 292.—Pleasure carriages.

CLASS 293.—Traveling carriages, coaches, stages, omnibuses, hearses.

Bath chairs, velocipedes, baby carriages.

CLASS 294.—Vehicles for movement of goods and heavy objects,—carts, wagons, trucks.

(For traction engines, see Group XVIII.)

CLASS 295.—Sleighs, sledges, sleds, etc.

CLASS 296.—Carriage and horse furniture, harness and saddlery, whips, spurs, horse-blankets, carriage robes, rugs, etc.

Parts of carriages,—wheels, bodies, shafts, etc.

Springs, axles.

Carriage iron work and fittings.

Carriage hardware.

Carriage varnish, oil, lubricants, etc.

GENERAL REPORT
OF THE
JUDGES OF GROUP XVII.

INTERNATIONAL EXHIBITION,
Philadelphia, 1876.

PROF. FRANCIS A. WALKER, *Chief of Bureau of Awards:*

SIR,—I have the honor to submit the report on exhibits and awards
in Group XVII.

Respectfully yours,

THOMAS GODDARD,
Chairman.

GROUP XVII.

CARRIAGES, VEHICLES, AND ACCESSORIES.

The Judges have examined in all some 353 exhibits, in pleasure-carriages, wagons, and sleighs; 73 of the pleasure-carriages from foreign countries, 169 of American construction; 81 business- and farm-wagons, 4 hearses, 1 sleigh from Russia, and 25 from different manufacturers in Canada and the United States. There were, moreover, exhibits in large number of harnesses, saddles, carriage- and harness-furniture, and hardware goods, some of which were from foreign countries, but most from the United States.

The number of awards is 166, of which 105 are to citizens of the United States, 51 to individual exhibitors from foreign countries, and 10, carrying diplomas without medals, to foreign corporations and municipalities whose exhibits were not intended for competition.

It may seem to many of our manufacturers that the number of awards bestowed upon exhibitors from abroad is large in proportion to those given to American exhibitors, but it must be remembered that exhibitors coming from long distances were under the necessity of undergoing heavy costs in packing, freight, and other incidental expenses, which wholly excluded any but the very best, and such as had been successful at previous Exhibitions, from sending their wares to compete with those who were well established, with a first-class reputation at home; while the opportunity which presented itself to home exhibitors was such as to induce a very large portion of them to send their wares, the small expense involved in getting their exhibit forwarded not being a matter greatly to be considered.

As this was the largest exhibition of carriages ever shown in the United States, or perhaps it is not too much to say the largest ever shown, so it must be considered equal to any in point of merit, if not, indeed, the very best display of wheel-carriages, in all their variety, ever exhibited at one time in any country. Here were carriages for display, arranged with drivers' seats and all the accompaniments of a stylish turn-out, of which coachmen and footmen form a conspicuous

part, as well as for those who drive themselves. Some carriages had elegant mountings and were splendidly equipped for promenade, while others were calculated to suit those of moderate means; and vehicles were shown in great variety to provide for the comfort of the family. The farmer found carriages so arranged as to be easily altered into commodious vehicles for the family, or to afford capacity for carrying numbers. Here, likewise, were sulkies and road-wagons, adapted to the wants of the sporting community, so lightly constructed that none but a professional driver would dare take up the reins. The Russian department contributed its specialty for fast driving; but its exceedingly low wheels, and the distance at which the horse is placed from his work, do not meet the American idea of a vehicle adapted to fast driving.

Norway sent its sulky with an arrangement easily adjusted to take the weight from the back of the horse,—well adapted, doubtless, to the country in which it is intended to be used; likewise an ancient sleigh, still in a good state of preservation, and to all appearance capable of further use, although represented to have been built in 1625. No style or variety of carriage seemed to be missing in the Exhibition. Baby-carriages and wagons were introduced without stint, of every known style and variety; some elaborately trimmed, painted, and ingeniously arranged, in price almost equal to larger carriages, others strongly built, well constructed and finished, at a price within the reach of all.

We can but speak in the highest terms of the great advance shown throughout this entire department of manufacture, and particularly in regard to the pleasure-carriages, where all were entitled to notice for their stylish and artistic appearance, general outline, adaptation for the purposes intended, excellent material and workmanship, and the exceedingly good taste displayed in their composition.

There were several exhibitors who have made carriage axle-trees and springs a specialty. Among them was a large and beautiful exhibit of the Collinge patent axle-trees from Germany. These axle-trees were exceedingly well finished, the boxes nicely fitted, the whole appearing a perfectly well-made article in every respect. The springs from the same maker were well proportioned, and laid up with an improved spring-head, said to give diminished friction at the bolt and impart more ease and elasticity to the springs. There were also Collinge patent axle-trees and carriage-springs from Paris, well made and finished, while in the box are grooves, said to be useful in conducting the oil from a chamber at the back of the box evenly along the entire arm of the axle-tree. The springs were very well drawn,

finished, and proportioned, and had a patent rubber coupling, calculated to prevent friction at the ends of the springs.

Excellent exhibits of elliptic springs appeared from Moscow, well made and proportioned; and in connection therewith, an excellent and ingenious machine for testing the strength and elasticity of the springs. From several manufacturers in the United States were shown large assortments of the different patterns of axle-trees now in use, with perfect adaptability to all the variety of carriages for which they are intended. The specimen of what is known as the "Collinge patent axle-tree" compared favorably with the best imported exhibit. This, though among the oldest patterns of oil axle-trees, still holds position as the best, and is used by all the leading carriage-manufacturers on the continent of Europe, and would heretofore have been adopted as the standard axle-tree in this country had not the cost of importation been so great as to prevent its general use.

The exhibition of springs from American manufacturers compared favorably with those from abroad, and showed as marked progress in this as any other department of carriage specialties. In carriage hardware, stump-joints, which until recently were all imported, are now manufactured by our ingenious mechanics, whose well-arranged machinery enables them to make a better article, at much less cost than the imported; and what is true of this can be said of the many other articles now furnished to the trade. Axle-tree clips, fifth or sweep wheels, carriage-bolts, etc., are now made so perfect and smooth that it is almost needless to finish them after they leave the forge, all produced, at much less expense, by the superior machinery used in the process of manufacture.

In carriage-wheels the mechanics of the United States are far in advance of all other known manufacturers. This can be readily accounted for by the abundance with which the best materials needful to be used in making wheels are found in this country, and the improved machinery employed in their production. A large variety, with beautiful specimens of workmanship and material, were shown at the Exhibition. It is a well-known fact that not only are exportations of bent rims, turned and finished spokes, and morticed hubs, called for from abroad, but wheels, made, tired, and finished complete, are now among the prominent articles of our export. The gas table shown in the Exhibition, for heating tires by gas, is worthy of especial notice, as it is always in readiness for use, and heats tires very quickly and evenly, a light tire requiring only from three to four minutes, the heaviest only six to eight minutes, for the required expansion, without scorching or burning the rim. Where steel tires are used it is a

great improvement, as they are annealed in the process of heating, and it is not needful to use water to cool them, as they have only been heated to expansion. This is done by gas, at a smaller expenditure than the cost of labor in preparing the wood for the ordinary furnace used for heating tires.

In harnesses there were many exhibitors from foreign countries, and a very large exhibit from numerous manufacturers in the United States. Among those from abroad requiring especial notice were those from the Russian Government at St. Petersburg and from Moscow, from Buenos Ayres, the Orange Free State, Brazil, Melbourne and Sidney, in Australia, and Kingston, Jamaica. All of these exhibits were of excellent workmanship and material, well adapted to their purposes, and every way calculated to suit the taste and wants of the several countries in which they were intended to be used. There was also from Paris a very elegant exhibit of double and single harnesses, which were made from excellent materials, in the most workmanlike manner, to correspond with the tasteful and beautiful exhibition of carriages from that country; while our American artisans exhibited harnesses made in the most elaborate style, with all the pains that could be bestowed upon them, and elegantly ornamented with costly fire-gilt, embossed trimmings, making the best and most showy display of materials and workmanship ever exhibited in this or any other country. They might well be considered works of art, so highly were they finished and decorated. Nor was there any deficiency in those made to supply all useful requirements. In short, it is not too much to say that there was never seen so large and excellent a collection of harnesses. Collars for horses, in all the various forms and kinds known to be in use, saddle-pads, fronts, harness loops, both useful and ornamental, were exhibited by those who make parts of harnesses a specialty. Saddlery hardware in all its varieties was shown of the richest and most elaborate patterns in gold- and silver-plated furniture for harnesses, and in rubber and gold-plated, and in celluloid mountings in fine and delicate colorings, with gold- and silver-plated linings, all of the very best, most highly decorated, and smoothly-finished work. Various styles and patterns of bridle-bits were shown by exhibitors who make this a specialty. Among those requiring particular notice is the flexible rubber bit, which is very well constructed, well made, strong, and seems to fill a much-needed want for an easy, safe, and soft bit for the horse's mouth. The "Star bridle-bit" has great power and ease combined, and is well adapted to all horses which are hard on the bit. Still another patented bridle-bit deserves mention, equipped with two bars,

the lower of which is movable, and can be adapted to the right position in the horse's mouth. This is a very ingenious and well-made bit, and is equally useful in driving a horse which presses hard or one which is light on the bit, or one which has the vile habit of putting the tongue out while in harness. Mexican bits and spurs were displayed, all well finished, and with power enough to punish any horse in the most severe manner and bring him into submission.

The exhibits also included bridle ornaments, monograms, initials in various forms and devices, and a large assortment of heraldic designs and chasings on gold and silver mountings, exquisitely executed. Tinned bridle-bits, buckles, terrets, etc., were also shown, manufactured and sold at prices almost incredibly low.

The exhibits in saddles and bridles were mostly from foreign countries. That sent from the National Museum of Egypt, and formerly used by the Viceroy, was one of the marked features in the Exhibition from this ancient and interesting country. There was also a Circassian saddle, mounted and finished in Damascus silver, with solid silver stirrups, richly and elaborately finished, to comport with the taste of the country; also, a Circassian saddle from Moscow, with cushion, made for use on long journeys; also, one hunting-saddle, with cushion. The largest contribution was from Toronto, Canada, constituting a very excellent display of the various styles of ladies' and gentlemen's riding-saddles, some of a costly and superior quality, others of a more common character, but all specimens of excellent materials and workmanship. Officers' saddles and bridles from the Army Arsenal of Brazil, saddles and bridles from St. Catharines, St. Paul's, and Rio Janeiro, Brazil, and from Queensland and Melbourne, Australia, each having some peculiarity in construction and material adapting them to the requirement of the several countries in which they were intended to be used.

A gentleman's and a lady's saddle, from Buenos Ayres, were made with much labor and painstaking, the lady's saddle being a very excellent specimen of ingeniously arranged ornamental stitching, with white saddlers' silk, by hand-labor, upon a rich blue velvet covering, showing immense patience and perseverance. Mexican riding-saddles and bridles, manufactured in New York, were splendid specimens of workmanship and good taste. But one other exhibit appeared which was manufactured in the United States.

Harness-makers' and saddlers' tools were exhibited, very well made, useful, and ingeniously contrived to save labor and produce excellent work, and were well deserving all the commendation bestowed upon them.

Whips in great variety were exhibited by London and Birmingham whip-makers, of the most elaborate design and finish, including riding-whips, with parasol attachment for ladies; all giving evidence of great skill, excellent taste in design and in the selection of choice and well-adapted materials; while the exhibits by American manufacturers, both in ornamental and useful designs, made a favorable impression when placed in comparison with those which have so long held superiority in this industry.

Feltings for saddle-cloths and saddle-pads, from Paris, of very superior quality; also from Saxony; and from the Wool Felt Co., Geingen, Würtemberg; saddle-cloths for ladies' and gentlemen's saddles, of good material, well made, some of them being very elaborately worked, were exhibited.

Ivory-work, inside coach-door handles, glass slides, and the usual assortment of ornamental articles made in this industry, were shown.

Business- and farm-wagons and carts have shared in the general improvement. We found a Western establishment which had the largest display in the Exhibition in this department, employing some 600 hands, and four hundred horse-power of steam, turning out, on an average, 60 wagons a day, or one in every ten minutes of all the working days in the year; their sales amounting to \$1,500,000 annually.

REPORTS ON AWARDS.

GROUP XVII.

1. McLear & Kendall, Wilmington, Del., U. S.

FOUR PLEASURE CARRIAGES.

Report.—Commended for good workmanship and material and very reasonable prices.

2. Wood Brothers, New York, N. Y., U. S.

SEVEN PLEASURE CARRIAGES.

Report.—Commended for very good workmanship, general good finish and outline; a handsome and large exhibit.

3. William D. Rogers & Co., Philadelphia, Pa., U. S.

SIX PLEASURE CARRIAGES.

Report.—Commended for uniform excellence, superior workmanship, perfection of finish, and elegance of style, in both heavy carriages and light wagons.

4. Pray Brothers, Boston, Mass., U. S.

ONE GODDARD PATTERN BUGGY, ONE TROTTING SULKY.

Report.—The finish and general workmanship are superior; likewise the patent axletrees, with spiral springs in place of washers, are worthy of special notice.

5. J. B. Brewster & Co., New York, N. Y., U. S.

SEVEN PLEASURE CARRIAGES.

Report.—Commended for good construction, workmanship, and materials; also for good style and finish; an extensive and creditable exhibit.

6. Charles S. Caffrey, Camden, N. J., U. S.

SIX LIGHT CARRIAGES.

Report.—Commended for good material, finish, and taste; well adapted for light work.

7. Joseph Beckhaus, Philadelphia, Pa., U. S.

FOUR PLEASURE CARRIAGES.

Report.—Commended for good general workmanship.

8. James Goold & Co., Albany, N. Y., U. S.

SLEIGHS AND CARRIAGES.

Report.—Heavy and light carriages and sleighs, all showing good and substantial workmanship, and at moderate prices.

9. James Hall & Son, Boston, Mass., U. S.

ONE GODDARD BUGGY AND ONE CUTTER SLEIGH.

Report.—Commended for good workmanship and finish.

10. R. M. Stivers, New York, N. Y., U. S.

THREE TOP WAGONS, ONE TWO-SEAT WARWICK, AND ONE SLEIGH.

Report.—Very good light carriages, including an excellent sleigh, all showing careful construction.

11. Henry Killam & Co., New Haven, Conn., U. S.

FIVE PLEASURE CARRIAGES.

Report.—An important exhibit, of excellent workmanship, good in design, and well finished.

12. Haskell Brothers, Philadelphia, Pa., U. S.

SIDE-BAR ROAD-WAGON WITH TOP.

Report.—A well-made wagon, with improved coupling or double-jointed connection-bar.

13. B. Manville & Co., New Haven, Conn., U. S.

FIVE PLEASURE CARRIAGES.

Report.—Good and substantial work; good in design, and well finished.

14. Hetfield & Jackson, Rahway, N. J., U. S.

TWO BUGGIES, ONE SKELETON WAGON, AND ONE SULKY.

Report.—Light wagons and sulkies. Commended for general good workmanship and very good finish.

15. F. C. Gilman, Montpelier, Vt., U. S.

ONE BOX WAGON AND ONE SULKY.

Report.—Commended for very good work.

16. A. McLear, West Chester, Pa., U. S.

ONE MOVABLE FRONT-SEAT ROCKAWAY.

Report.—Commended for general good workmanship.

17. Wm. Youle, Norwalk, Conn., U. S.

TWO HEARSE.

Report.—Good work, handsomely and richly ornamented.

18. Abbott Downing Co., Concord, N. H., U. S.

ONE ROAD COACH, ONE ROAD COACH FOR ROUGH USE (ALSO CALLED "MUD COACH").

Report.—Commended as excellent for the purpose, strong and durable.

19. Charles Behlen, Cincinnati, Ohio, U. S.

ONE CHILD'S HEARSE.

Report.—Commended for very rich and elaborate work and handsome finish.

20. James Cunningham & Son, Rochester, N. Y., U. S.

CARRIAGES, WAGONS, AND HEARSE—THREE CARRIAGES, TWO LIGHT WAGONS, ONE HEARSE.

Report.—Commended for general good work with elaborate trimmings.

21. Hugh Smith, Gray, Me., U. S.

TWO SLEIGHS.

Report.—Iron work of novel pattern, well and economically constructed; well adapted to intended purpose; offered at low price.

22. C. S. Windover, Long Acre, London, England.

FOUR PLEASURE CARRIAGES.

Report.—Commended for good taste in the general proportions and finish, good light workmanship. The vehicle called "Empress of Austria's brougham" is noticeable for very complete and interesting details, such as ventilator at the top, a reading-light at the back, and a ratchet latch to hold the glass up to any desired height.

23. McNaught & Smith, Worcester and London, England.

FOUR PLEASURE CARRIAGES.

Report.—Good light workmanship; graceful style; well adapted for pleasure riding.

24. Charles Thorn, Norwich, England.

EIGHT CARRIAGES, VIZ., ONE BREAK, ONE SQUARE LANDAU, ONE PARISIAN PHAETON, ONE SPORTING CART, ONE WAGONETTE, ONE GIG, ONE CIRCULAR, ONE CIRCULAR BROUGHAM, AND ONE VICTORIA.

Report.—A large and very creditable exhibit. The workmanship, style, and finish of the objects shown are alike commendable. The break and wagonette deserve special notice.

25. Thomas Peters & Son, London, England.

NINE CARRIAGES.

Report.—Commended for great variety of forms and patterns, sound and substantial construction. The "road drag" is especially well adapted to the purpose for which it is intended.

26. Hooper & Co., London, England.

SIX CARRIAGES, VIZ., ONE LANDAU, ONE C-SPRING BAROUCHE, ONE PARK PHAETON, ONE MINIATURE BROUGHAM, ONE VIENNA PHAETON, ONE DRAG.

Report.—The carriages exhibited by this firm, for correctness of outline, general form, perfect adaptation for the purposes intended, harmonious combination of colors, excellent material and workmanship, entitle them to the highest commendation; the "Vienna phaeton" and "drag" especially.

27. Wm. Kew & Son, Beamsville, Ontario, Canada.

TWO-SEAT DOG-CART SLEIGH.

Report.—Commended as well built and well suited to the purpose for which it is intended, and offered at a remarkably low price.

28. B. Ledoux, Montreal, Canada.

SEVEN-PASSENGER SLEIGH.

Report.—By means of a sliding arrangement under the front seat, the capacity of this sleigh may be reduced at pleasure to five instead of seven. It is quite ingenious and well and substantially built.

29. John M. De Wolfe, Halifax, Nova Scotia.

THREE LIGHT CARRIAGES.

Report.—General sound work and good finish; the more commendable when the lack of facilities for carriage-building in Halifax is taken into consideration.

30. Stevenson & Elliott, Melbourne, Victoria, Australia.

LANDAU.

Report.—Commended for general good work and construction; and had not this carriage been damaged by salt water on the way here, it would have compared not unfavorably with the best work entered for competition.

31. N. Huret, Paris, France.

CYNOPHORE, OR DOG CARRIAGE.

Report.—Commended as light and elegant in construction, well adapted to the purpose for which it is intended, and one of the most novel and original articles that has fallen under our notice.

32. Binder Brothers, Paris, France.

PLEASURE CARRIAGES.

Report.—Commended for superior workmanship, general good taste and elegance of outlines and trimmings, well-constructed bodies, excellent colors and finish. We note particularly a superb barouche and a “break” (or char-à-bancs).

33. Desouches, Paris, France.

SEVEN PLEASURE CARRIAGES.

Report.—A very complete exhibit of handsome carriages, of various styles and models, among them a small brougham provided with an indicator to facilitate communication between the passengers and the driver.

34. Mühlbacher, Paris, France.

SIX PLEASURE CARRIAGES.

Report.—Commended for good workmanship and general style. A double-top sociable is quite novel; and we note also a handsome eight-spring sociable.

35. Joseph Wernik, Warsaw, Russia.

ONE SLEIGH.

Report.—Commended for good, substantial, and serviceable work, well adapted to the purposes intended.

36. Nicholas Arbatsky, Moscow, Russia.

ONE SLEIGH, FUR ROBE ATTACHED.

Report.—Commended as well built and finished, thoroughly adapted to the purpose for which it is intended.

37. Charles Nellis, St. Petersburg, Russia.

ONE CARRIAGE (VICTORIA).

Report.—Commended for good general workmanship and finish; very stylish, and built sufficiently strong to meet the requirements of the rough roads of that country.

38. Sorensen & Klovstad, Christiania, Norway.

THREE LIGHT CARRYALLS (TWO-WHEEL SULKIES).

Report.—Commended as neatly and strongly built, well adapted to the country where used, and sold at a low price.

39. L. Heffermehl, Drammen, Norway.

ONE SLEIGH, AND ONE TWO-WHEEL CARRYALL OR SULKY.

Report.—Commended for good, substantial work, well suited to the country where used, and furnished at very low figures.

40. Philip Ketterer, New York, N. Y., U. S.

ONE-HORSE PACKAGE DELIVERY WAGON, WITH SAFETY WIRE GRATING.

Report.—Commended as well made, neatly finished, and useful.

41. W. & L. Wenkenbach, Philadelphia, Pa., U. S.

BEER WAGON.

Report.—Commended for very fine workmanship, both in iron and wood, and handsomely finished for the purpose intended.

42. Ch. Rauch, Cleveland, Ohio, U. S.

ICE WAGON.

Report.—A large, strong, and useful object, well constructed for handling ice easily, and an improvement upon ice wagons now in use.

43. Studebaker Brothers Manufacturing Co., South Bend, Ind., U. S.

FREIGHT, TRANSPORT, AND FARM WAGONS.

Report.—All strong, durable work, of the best material and workmanship, and thoroughly adapted to the uses for which it is intended.

44. Joseph Kieser, New York, N. Y., U. S.

ONE FOUR-HORSE BREWER'S WAGON.

Report.—Commended for very fine work, and well adapted to the purpose intended.

45. Jacob Sebastian, New York, N. Y., U. S.

ONE-HORSE TRUCK, ONE COVERED TWO-SEAT WAGON (EXPRESS OR DELIVERY).

Report.—Superior workmanship, well finished, and thoroughly adapted to the intended uses.

46. Winchester & Partridge Manufacturing Co., Whitewater, Wis., U. S.

TWO PLANTATION WAGONS, AND ONE FREIGHT WAGON.

Report.—Very strongly and substantially built, and well adapted to intended uses.

47. Wilson, Childs, & Co., Philadelphia, Pa., U. S.

FIVE TWO-WHEEL AND FOUR-WHEEL CARTS AND WAGONS.

Report.—Good, substantial, and useful articles, and well adapted to intended uses.

48. Fulton, Walker, & Co., Philadelphia, Pa., U. S.

ONE HEAVY FOUR-HORSE EXPRESS WAGON, THREE LIGHT ONE-HORSE DELIVERY WAGONS.

Report.—Commended for good workmanship and material, and for good finish.

49. Geo. Lengert & Son, Philadelphia, Pa., U. S.

TWO TWO-HORSE AND TWO ONE-HORSE PACKAGE DELIVERY WAGONS.

Report.—Very good, strong, and well finished. One of the single-horse wagons in particular is very finely finished for the Exhibition.

50. Peter Schuttler, Chicago, Ill., U. S.

WAGONS—ONE LARGE FREIGHT WAGON, TWO "ELLIPTIC SPRINGS" FARMER'S DRIVING WAGONS, AND ONE FARM WAGON.

Report.—Commended for good, substantial, and durable work.

51. W. T. & E. A. Rogers, Quincy, Ill., U. S.

TWO FARM WAGONS.

Report.—Commended as strong, substantial, and well built.

52. Fish Brothers & Co., Racine, Wis., U. S.

TWO FARM WAGONS.

Report.—Good strong work, and in every way useful.

53. John Beggs & Sons, Philadelphia, Pa., U. S.

ONE HEAVY TRUCK, ONE LIGHT PACKAGE DELIVERY WAGON.

Report.—Commended as well built, strong, durable, and neatly finished.

54. C. Schanz, Philadelphia, Pa., U. S.

TWO LIGHT EXPRESS WAGONS.

Report.—Well-built, strong, and useful wagons.

55. Dann Brothers & Co., New Haven, Conn., U. S.

BUGGY BODIES AND SEATS (UNPAINTED), AND BENT CARRIAGE WOODWORK.

Report.—Good material, well made, the wood nicely bent.

56. Philip Lebzetter & Co., Lancaster, Pa., U. S.

SHAFTS, WHEELS, AND WHEEL STOCK.

Report.—A good exhibit of bent rims and shafts. Commended for good material and good workmanship.

57. John G. Davis & Son (Union Spoke, Hub, and Rim Works), Philadelphia, Pa., U. S.

WHEELS AND WHEEL STOCKS.

Report.—Commended for good material and good workmanship.

58. Strahorn, Pierson, & Co., Toughkenamon, Chester County, Pa., U. S.

WHEELS AND WHEEL STOCK.

Report.—A novel wheel, with patent iron hub; worthy of commendation.

59. Union County Manufacturing Co., Elizabeth, N. J., U. S.

WHEELS AND WHEEL STOCK.

Report.—Good wheels, fine stock, and altogether a very nice exhibit.

60. New Haven Wheel Co., New Haven, Conn., U. S.

WHEELS AND WHEEL STOCK.

Report.—Commended for good quality and good workmanship.

61. Phineas Jones & Co., Newark, N. J., U. S.

WHEELS AND BENT WOOD, ALSO EXHIBITED IN ONE SULKY AND ONE SKELETON WAGON.

Report.—Good material, well made, strong, and furnished at a moderate cost.

62. S. N. Brown & Co., Dayton, Ohio, U. S.

WHEELS AND WHEEL STOCK, WHIFFLE-TREES, AND SHAFTS.

Report.—Commended for excellent choice of material, and good workmanship.

63. John Urmston, Rahway, N. J., U. S.

HUBS.

Report.—Very good stock and very well made.

64. Jacob A. Leippe (Anchor Bending Works), Lancaster, Pa., U. S.

BENT WOOD FOR RIMS AND SHAFTS.

Report.—Good material, and well bent.

65. Hoopes, Brother, & Darlington, West Chester, Pa., U. S.

WHEELS, WHEEL STOCK AND BENT WOODS.

Report.—Commended for a large and very elegant exhibit, choice material, and excellent workmanship.

66. **Hunt, Cairns, & Co., St. Catherine, Ontario, Canada.**

WHEELS AND WHEEL STOCK.

Report.—Commended for good material and workmanship.67. **Samuel G. Reed, Wellesley, Mass., U. S.**

APPARATUS FOR HEATING CARRIAGE TIRES BY MEANS OF GAS JETS.

Report.—Tires can be heated by this process as fast as workmen can set them; is always ready; and heats tires to the required expansion, very evenly and at a very small cost.68. **Benezet & Co., Philadelphia, Pa., U. S.**

CARRIAGE SPRINGS.

Report.—A large and fine exhibit of C and elliptic springs; commended for good material and workmanship.69. **M. Seward & Son, New Haven, Conn., U. S.**

AXLE-TREE CLIPS.

Report.—Commended as well made and of excellent material.70. **D. Dalzell & Sons, South Egremont, Mass., U. S.**

CARRIAGE AXLES.

Report.—A fine exhibit of assorted axles, of good workmanship and material.71. **Sheldon & Co., Auburn, N. Y., U. S.**

CARRIAGE AXLES.

Report.—A very fine display of axles; commended for excellent material and superior workmanship.72. **Topliff & Ely, Elyria, Ohio, U. S.**

BOW SOCKETS AND SIDE SPRING CONNECTING-RODS.

Report.—Novel, very useful, and good articles.73. **Samuel E. Tompkins & Co., Newark, N. J., U. S.**

SILVER-PLATED COACH AND HARNESS HARDWARE.

Report.—Commended for good and useful general work.74. **Hayden & Smith, Auburn, N. Y., U. S.**

CARRIAGE HARDWARE.

Report.—A very fair exhibit of fifth wheels, shaft couplings, etc.75. **Chris. Kunzig, Philadelphia, Pa., U. S.**

"CLOSE PLATED" CARRIAGE WARE.

Report.—Very nice work, very durable and useful; an excellent display.76. **Welsh & Lea ("Coleman Eagle Bolt Works"), Philadelphia, Pa., U. S.**

WROUGHT-IRON BOLTS.

Report.—Commended for excellent work, superior material, and strength.

77. Peel & Elster, Springfield, Ohio, U. S.

CARRIAGE DASHER MOULDING OF STEEL, BLACK OR PLATED.

Report.—Useful, novel articles, well made and well finished.**78. H. F. Osborne, Newark, N. J., U. S.**

MACHINES FOR SPLITTING LEATHER AND ROUNDING HAND REINS AND TRACES.

Report.—Well-constructed and useful machines.**79. A. Albright, Newark, N. J., U. S.**

HARD RUBBER-COATED HARNESS AND CARRIAGE TRIMMINGS.

Report.—Very good work, artistic designs, nicely and richly finished.**80. Chr. Sippel, Newark, N. J., U. S.**

FANCY HANDLES, AND CARD CASES, FOR CARRIAGE TRIMMING.

Report.—Well-made, nice, and useful articles.**81. White Manufacturing Co., Bridgeport, Conn., U. S.**

CARRIAGE LAMPS AND METAL FURNITURE FOR CARRIAGES AND HEARSEs.

Report.—Very good workmanship and finish, useful articles, and well adapted to the intended purposes. We note especially a new patent adjustable dasher-lamp, for driving and sporting purposes.**82. H. D. Smith & Co., Plantsville, Conn., U. S.**

CARRIAGE MAKERS' FORGED IRONS.

Report.—A large and splendid exhibit of superior, useful, and practical articles.**83. A. Shitoff, Moscow, Russia.**

ELLIPTIC SPRINGS AND SPRING-TESTER.

Report.—Springs well made and well proportioned. The machine is an excellent one for the purpose.**84. Edward Schmidt, St. Petersburg, Russia.**

AXLE-TREES AND BOXES.

Report.—Commended as well forged, nicely finished, and of excellent material.**85. Dick & Kirschten, Offenbach-on-the-Main, Germany.**

CARRIAGE AXLES, SPRINGS, AND FORWARD GEARS.

Report.—A large and very superior exhibit of "C" and "elliptic" springs, axles and carriage iron work.**86. G. Anthoni, Paris, France.**

AXLE-TREES AND CARRIAGE SPRINGS.

Report.—Commended as well made and nicely finished. The axles have a groove for the purpose of oiling. The springs are provided with a nicely arranged rubber coupling.

87. **Stimson & Babcock, Boston, Mass., U. S.**

COACH AND CAR VARNISHES.

Report.—A fine exhibit. A handsome black panel finished with these varnishes serves to illustrate their merits.

88. **C. T. Reynolds & Co., New York, N. Y., U. S.**

CARRIAGE VARNISHES.

Report.—A large and elegant exhibit of varnishes. A number of carriage wheels and a miniature coach finished with their varnishes are exhibited to illustrate their qualities.

89. **Felton, Rau, & Sibley, Philadelphia, Pa., U. S.**

CARRIAGE VARNISHES.

Report.—A large and handsome display of carriage varnishes.

90. **C. C. Phillips & Co., Philadelphia, Pa., U. S.**

CARRIAGE VARNISHES.

Report.—A large and elegant exhibit, handsomely put up in neat packages for carriage-makers' use.

91. **D. Rosenberg & Sons, New York, N. Y., U. S.**

CARRIAGE VARNISHES.

Report.—An elegant exhibit of varnishes for carriage-makers.

92. **Valentine & Co., New York, N. Y., U. S.**

COACH AND CAR VARNISHES.

Report.—A full display of varnishes for carriage and railway-car makers' use. The merits and qualities of these varnishes are fully sustained by numerous testimonials and affidavits of parties who have used them, and by the presence in the Exhibition of many carriages, by the best makers in the country, which have been finished with them, and furnish further positive proof of the great excellence of these varnishes in working quality, color, brilliancy, and durability.

93. **Edward Smith & Co., New York, N. Y., U. S.**

CARRIAGE VARNISHES.

Report.—Carriage varnishes in great variety and handsomely displayed.

94. **Haynes & Jefferis, Coventry, England.**

FOUR ARIEL VELOCIPEDES (ONE OF WHICH WITH A WHEEL SEVEN FEET IN DIAMETER),
ONE TANGENT VELOCIPED.

Report.—Very superior work, light, and nicely constructed.

95. **Digley & Roberts, Coventry, England.**

TWO "SPIDER" BICYCLES.

Report.—Commended for good workmanship and graceful designs.

96. F. Herrmann Jury, New York, N. Y., U. S.

CHILDREN'S CARRIAGES (FOLDING TO CARRY BY HAND).

Report.—Commended as good, useful, and ingenious.

97. George P. Steinbach, Baltimore, Md., U. S.

CHILDREN'S CARRIAGES.

Report.—A nice carriage, easily converted into a sleeping-carriage.

98. J. A. Crandall, Brooklyn, N. Y., U. S.

CHILD'S CARRIAGE AND ROCKING-HORSE, CHILD'S CARRIAGE CONVERTIBLE INTO A CRADLE, CHILD'S SLED CONVERTIBLE INTO A SEE-SAW OR HIGH CHAIR, ROCKING-HORSE ON SPRINGS.

Report.—Commended for useful improvements in baby carriages.

99. Newgeon & Shelton Carriage Co., Birmingham, Conn., U. S.

CHILD'S CARRIAGE.

Report.—An ingenious and well-constructed vehicle, convertible into bed or cradle, richly and handsomely trimmed, ornamented, and finished.

100. Charles Thomson, London, England.

THREE-WHEEL PERAMBULATOR.

Report.—A nicely made child's carriage, the strongest constructed shown at the Exhibition.

101. J. A. Yost, Philadelphia, Pa., U. S.

THREE CHILDREN'S CARRIAGES, ONE THREE-WHEEL VELOCIPEDE.

Report.—Commended as well made and containing valuable improvements for the safety and comfort of children.

102. Richardson, McKee, & Co., Boston, Mass., U. S.

CHILDREN'S CARRIAGE.

Report.—A very superior and nicely constructed child's carriage.

103. J. A. Conover & Son, New York, N. Y., U. S.

CHILDREN'S CARRIAGE AND WOODEN HORSE.

Report.—The "Leaping" horse on eight spiral springs is a handsome and useful toy, and well made.

104. Montpelier Manufacturing Co., Montpelier, Vt., U. S.

FIVE CHILDREN'S CARRIAGES.

Report.—Good work, and well constructed.

105. Paris Hill Manufacturing Co., Paris Hill, Me., U. S.

GOAT WAGONS AND CHILDREN'S SLEDS.

Report.—Good substantial work, and furnished at very moderate prices.

106. L. P. Tibbals, New York, N. Y., U. S.

TWO CHILDREN'S CARRIAGES.

Report.—Commended for useful improvements in the way of a movable umbrella-shaped sun-shade, and changing the carriage from one to two seats at pleasure.

107. Cole & Ballard, Newark, N. J., U. S.

THREE CHILDREN'S CARRIAGES, ONE THREE-WHEEL VELOCPEDE.

Report.—A variety of good models, and well made.

108. St. Petersburg Arsenal, St. Petersburg, Russia.

FOUR PACK-SADDLES FOR CARRYING MOUNTAIN ARTILLERY, ONE AMBULANCE, AND ONE COMMISSARY WAGON.

Report.—Good material, good workmanship, useful articles, and well adapted to purposes of war.

109. Government of the Orange Free State, South Africa.

DOUBLE AND SINGLE HARNESS OF RUSSET LEATHER, AND ONE MODEL OF A TRANSPORT WAGON.

Report.—Commended for very good work throughout.

110. Provincial Commission of San Luis, Argentine Republic.

SOUTH AMERICAN SADDLES WITH CREASED LEATHER HOUSINGS.

Report.—Commended as very handsome work, strong and substantial, and very moderate in price.

111. Francisco Gomes dos Santos Lima, San Paulo, Brazil.

SOUTH AMERICAN SADDLES, WITH HOUSINGS, LASSOS, ETC.

Report.—Handsome handwork, fine workmanship, very cheap, and well adapted to purposes intended.

112. A. Luis d'Almeida, San Paulo, Brazil.

SOUTH AMERICAN SADDLE AND BRIDLE (THE LATTER OF THREAD WITH THREAD BIT).

Report.—Commended as remarkable work, offered at very low prices, and well adapted to the country where used.

113. Sheriff of Queensland, Australia.

STOCKMAN'S AND GENTLEMAN'S MOUNTAIN SADDLES; ALSO ONE PACK-SADDLE.

Report.—Good, useful work, and well adapted to the intended use.

114. Wurtemberg Wool Felt Co, Giengen-on-the-Brenz, Germany.

FELTS FOR HARNESS AND SADDLERY PURPOSES.

Report.—Excellent material, and well adapted to the purposes intended.

115. National Museum, Cairo, Egypt.

SADDLES AND SADDLERY.

Report.—A large and interesting display of saddles and bridles for horses, mules, donkeys, camels, and dromedaries. We note particularly one very elaborate saddle and saddle-cloth richly embroidered and embossed in gold, for the use of the Viceroy of Egypt.

116. Provincial Commission of San Juan, Argentine Republic.

SOUTH AMERICAN SADDLE AND BRIDLE, MOUNTED THROUGHOUT IN SOLID SILVER.
COST, \$350.

Report.—Commended for very rich, elaborate, and ornamental work.

117. Army Arsenal, Rio de Janeiro, Brazil.

CAVALRY SADDLE AND BRIDLE, ONE OFFICER'S SADDLE STITCHED IN BRASS, AND ARTIL-
LERY SADDLE AND BRIDLE.

Report.—Very good work, strong, well made, and thoroughly adapted to the purpose.

118. Provincial Commission of the Province of Tucuman, Argentine Republic.

LADIES' SADDLES, RAWHIDES, REINS, AND BRIDLES.

Report.—Commended for handsome and very substantial work.

119. Provincial Commission of Catamarca, Argentine Republic.

BRIDLES AND SADDLE-CLOTH OF VIZCACHA LEATHER.

Report.—Superior workmanship and useful articles.

120. Provincial Commission of Cordoba, Argentine Republic.

REINS, BRIDLES, AND GIRTHS OF RAWHIDE, AND LEATHER HOUSINGS.

Report.—Commended for strong, useful, and substantial work.

121. A. Lynch, Philadelphia, Pa., U. S.

HARNESS.

Report.—Commended as made of good material, substantial work, well mounted and trimmed, and all made with the exhibitor's own hands.

122. T. T. A. Guimarães, Rio Janeiro, Brazil.

TWO SADDLES ON THE ENGLISH MODEL.

Report.—Commended as well made and of excellent workmanship.

123. Ambrosius Marthaus, Oschatz, Germany.

HARNESS FELTS AND FELTINGS.

Report.—A fine display of felts and feltings for saddle-pads and saddle-cloths, harness, etc., in great variety of thickness and color; good quality, and some of them very elaborately worked.

124. Eugenio Mattaldi, Buenos Ayres, Argentine Republic.

LADIES' AND GENTLEMEN'S SADDLES.

Report.—Fine workmanship, very rich and elaborate, and all made by hand. We note particularly a gentleman's saddle made so as to be taken apart in five minutes, and a lady's blue velvet saddle stitched in silver.

125. S. & H. Borbridge, Ottawa, Ontario, Canada.

HARNESS AND SADDLES.

Report.—The saddles are well made, of good material, and display good workmanship.

126. Michael Elenin, Moscow, Russia.

TWO SETS HARNESS, FOR CITY USE, ONE TROIKA HARNESS FOR THREE HORSES, SILVER MOUNTED AND WITH ARCH NECK-PIECE FOR CENTRE HORSE.

Report.—Good material, good workmanship, and well suited to the taste of the country and the purposes intended.

127. Juan Videla, Buenos Ayres, Argentine Republic.

GENTLEMAN'S SADDLE.

Report.—Commended for a vast amount of skillful work in "hand creasing;" handsome and useful.

128. Christof Neuner, Klagenfurt, Austria.

HARNESS, LOOPS, AND CRUPPER.

Report.—A handsome double harness, silver mounted, well made, and suited to the country where used; the loops and cruppers well made and useful.

129. Stephen Shishkin, Moscow, Russia.

DOUBLE AND SINGLE HARNESS, MOUNTED IN GILT.

Report.—Good material, well made, and well adapted to the use and taste of the country; furnished at moderate prices.

130. Paul Koorikof, St. Petersburg, Russia.

ONE COSSACK SADDLE, HARNESS FOR FIELD ARTILLERY, FIRE ENGINE, AND COMMISSARY TRAIN; RAWHIDE STRAPS, AND TWINE.

Report.—Commended as all of excellent material and workmanship, useful, well adapted to the country and the purposes intended. We note the six-horse harness for field artillery, with a new style breast-piece or collar, capable of being altered in size so as to fit easily the smallest as well as the largest horse.

131. Swaine & Adeney, London, England.

RIDING AND DRIVING WHIPS.

Report.—Commended as very superior work, elegantly finished, and in good taste.

132. Robert Malcom, Toronto, Ontario, Canada.

ONE SET EXTRA LARGE AND HEAVY DRAY HARNESS FINISHED FOR DISPLAY; ONE SET EXTRA LARGE AND HEAVY DRAY HARNESS FINISHED FOR WORK; TEN LADIES' AND GENTLEMEN'S SADDLES OF VARIOUS WEIGHTS AND PATTERNS.

Report.—Commended as fine substantial work and well adapted to the intended uses.

133. Davis & Wilson, Birmingham, England.

WHIPS.

Report.—A large and very good exhibit of whips; substantial and tasteful work.

134. Wade Bothwell, Melbourne, Victoria, Australia.

HARNESS, SADDLES, AND STOCKMEN'S WHIPS.

Report.—Commended as good work and well adapted to the uses for which it is intended.

135. P. Guerin, Sydney, New South Wales, Australia.

SADDLES.

Report.—Commended for good substantial work and low prices.

136. R. Zimmermann, Moscow, Russia.

ONE CIRCASSIAN SADDLE AND BRIDLE; ONE HUNTING SADDLE AND BRIDLE; ONE SET SILVER MOUNTED HARNESS FOR CITY USE.

Report.—Commended as being all nice workmanship and material, and well adapted to the country where used.

137. Wm. Vahey, Forrest, Ontario, Canada.

HORSE COLLARS AND COLLAR BLOCK.

Report.—The collar block is a good, useful, and economical article.

138. Fortin Brothers, Paris, France.

HARNESS FELTS.

Report.—A fine assortment of harness felts in various thicknesses, colors, and qualities, for saddlers', harness-makers' and shoemakers' use; well made, strong, and durable, and well adapted to the uses for which they are intended; also furnished at very moderate prices.

139. K. Hodjaef, St. Petersburg, Russia.

ONE CIRCASSIAN SADDLE, MOUNTED AND FINISHED IN DAMASCUS SILVER, WITH SOLID SILVER STIRRUPS.

Report.—Commended as very fine, elaborate, and artistic, and finished in extra good taste and style for the country where used.

140. A. A. A. Guimarães, Rio de Janeiro, Brazil.

LADY'S SIDE-SADDLE.

Report.—Commended as well made and beautifully stitched.

141. Nicolau Schmitt & Co., S. Leopoldo, Brazil.

THREE SADDLES.

Report.—Commended for good workmanship and rich ornamentation.

142. F. S. Lyman, Hawaii, Sandwich Islands.

SPANISH SADDLE AND BRIDLE.

Report.—Very good, useful work.

143. Samuel R. Phillips, Philadelphia, Pa., U. S.

HARNESSES.

Report.—An extensive and excellent display of fine harness in great variety; good substantial work, with mountings, and deserving great credit.

144. H. G. Hædrich & Sons, Philadelphia, Pa., U. S.

HARNESS.

Report.—Very fine work, highly finished, of good material; rich, elaborate, and artistic.

145. James R. Hill & Co., Concord, N. H., U. S.

HARNESSES.

Report.—A most excellent exhibit of harness of every grade, of superior workmanship, excellent material, thoroughly adapted to every purpose for which harness is used, and at reasonable prices.

146. Crane & Co., Newark, N. J., U. S.

HARNESS AND SADDLERY HARDWARE.

Report.—A large and handsome exhibit. The flexible rubber bits are very nicely constructed, well made, and seem to fill a much-needed want for an easy, soft, and safe bit for a horse's mouth.

147. George Motts, Washington, D. C., U. S.

SINGLE HARNESS OF RUSSET LEATHER.

Report.—Superior workmanship, excellent material, very light, and well finished.

148. C. M. Moseman & Brother, New York, N. Y., U. S.

FIRE-ENGINE HARNESS.

Report.—Commended for usefulness and good adaptation to the purpose of rapidly fastening horses.

149. Sallada & Pearson, Philadelphia, Pa., U. S.

RIDING AND DRIVING WHIPS.

Report.—Commended as well made, strong, and richly mounted in gold and silver.

150. American Whip Co., Westfield, Mass., U. S.

RIDING AND DRIVING WHIPS, WHIP THONGS, AND LASHES.

Report.—Commended for good workmanship and material, and good finish.

151. Korne & Currie, New York, N. Y., U. S.

SINGLE AND DOUBLE HARNESS.

Report.—A good exhibit of substantially made and richly decorated harness.

152. Weaver & Bardall (Western Penitentiary), Pittsburg, Pa., U. S.

TEAMSTERS' WHIPS.

Report.—Commended as well made, strong, useful, and serviceable.

153. Patrick McFadden, Philadelphia, Pa., U. S.

SINGLE HARNESS, OPTIC SHIELD, AND CART SADDLE.

Report.—The cart saddle is a useful and substantial article, and well made.

154. Peters & Calhoun Co., Newark, N. J., U. S.

DOUBLE HARNESS AND MEXICAN RIDING SADDLES.

Report.—The Mexican riding saddles are of very fine workmanship, handsome and elegant of the kind.

155. Richard P. Whelan, New York, N. Y., U. S.

BRIDLE BIT, KNOWN AS THE "STAR" BIT.

Report.—A useful, well-made article, combining ease and power.

156. John C. Lighthouse, Rochester, N. Y., U. S.

HORSE COLLARS.

Report.—Commended for great variety and superior quality of collars. The zinc collar pad, leather-covered, deserves special mention for originality and usefulness.

157. A. S. Jenks, Philadelphia, Pa., U. S.

ADJUSTABLE DRIVING BITS.

Report.—An ingenious article for hard-mouthed horses, well made, and perhaps as well suited and as safe a bit for the purpose as we have any knowledge of.

158. Thomas Moore, New York, N. Y., U. S.

HORSE COLLARS.

Report.—A very fine exhibit of plain and fancy horse collars, well made and of good material.

159. J. Lyman Wilder, Hartford, Conn., U. S.

BRIDLE FRONTS AND SADDLE PADS.

Report.—Neatly made and very good work.

160. R. F. Wilson, Milton, Pa., U. S.

LEATHER FLY NETS.

Report.—They are ingenious, well made, and durable, and very useful for the purpose intended.

161. Hawkins Brothers, Walsall, England.

GENERAL SADDLERY IRON WORK.

Report.—Very nice articles; good work, well finished, and useful.

162. Kessler & Brothers, Philadelphia, Pa., U. S.

WOODEN HAMES FOR HEAVY HARNESS.

Report.—Good, useful articles, well made, strong, and durable.

163. Charles M. Theberath & Brother, Newark, N. J., U. S.

SADDLERY HARDWARE AND HARNESS TRIMMINGS.

Report.—Commended for elegant and artistic work.

164. Samuel Reynolds & Co., Pittsburg, Pa., U. S.

SADDLERY HARDWARE AND IRON HAMES.

Report.—A fine assortment of nicely trimmed bits, buckles, etc.; good, plain, and substantial, and furnished at wonderfully low prices.

165. C. S. Osborne & Co., Newark, N. J., U. S.

SADDLERS' AND HARNESS-MAKERS' TOOLS.

Report.—Very good articles, well made, durable, and useful.

166. Aug. Buerman, Newark, N. J., U. S.

SADDLERY AND HARNESS HARDWARE.

Report.—An assortment of Mexican bits and spurs, well made and excellently suited to the countries where they are intended to be used.

167. J. V. Waldron & Brother, New York, N. Y., U. S.

CRESTS, COATS OF ARMS, MONOGRAMS, AND BITS FOR HARNESS.

Report.—A fine exhibit of gold and silver plated articles for harness mountings, nicely executed, well made, and good designs.

168. H. Rosenthal, New York, N. Y., U. S.

HORSE BRUSHES.

Report.—Commended for excellent quality of workmanship and material.

SIGNING JUDGES OF GROUP XVII.

The figures annexed to the names of the Judges indicate the reports written by them respectively.

M. GUIET, 1, 22, 23, 24, 25, 26, 27, 31, 32, 33, 34, 35, 36, 37, 38, 39, 68, 69, 72, 83, 84, 86, 87, 99, 100, 108, 112, 117, 121, 122, 126, 129, 130, 136, 138, 139, 140, 141, 146, 148.

THOMAS GODDARD, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 30, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 52, 53, 55, 56, 57, 58, 59, 60, 61, 62, 64, 65, 67, 70, 71, 74, 75, 76, 77, 79, 80, 81, 82, 85, 88, 89, 90, 91, 92, 93, 95, 96, 97, 98, 101, 102, 103, 104, 105, 106, 107, 109, 110, 111, 114, 115, 118, 120, 123, 124, 127, 128, 143, 144, 147, 151, 153, 154, 155, 158, 163, 167.

WILLIAM DUFFUS, 4, 50, 51, 66, 94, 113, 125, 131, 132, 133, 134, 135, 137, 145, 149, 150, 152, 156, 161, 162, 168.

B. F. MORSE, 21, 28, 29, 54, 63, 73, 78, 116, 119, 142, 157, 159, 160, 164, 165, 166.

SUPPLEMENT TO GROUP XVII.

REPORTS OF JUDGES ON APPEALS.

JUDGES.

JOHN FRITZ, Bethlehem, Pa.
EDWARD CONLEY, Cincinnati, Ohio.
CHARLES STAPLES, Jr., Portland, Me.
BENJ. F. BRITTON, New York City.
H. H. SMITH, Philadelphia, Pa.

COLEMAN SELLERS, Philadelphia, Pa.
JAMES L. CLAGHORN, Philadelphia, Pa.
HENRY K. OLIVER, Salem, Mass.
M. WILKINS, Harrisburg, Oregon.
S. F. BAIRD, Washington, D. C.

1. J. L. H. Mosier, New York, N. Y., U. S.

CARRIAGE IRON-WORK.

Report.—Commended as a good display of carriage iron-work in parts, the king-bolts and perch-coupling being especially meritorious, showing new and valuable improvements in construction.

2. The Hart, Bliven, & Mead Manufacturing Co., Kensington, Conn., and New York, N. Y., U. S.

CARRIAGE TRIMMINGS, COMPRISING BANDS AND SOCKETS.

Report.—Commended as substantially made, well finished, economical in cost, and adapted to the purpose intended.

3. Middletown Tool Co., Middletown, Conn., U. S.

HARNESS SNAPS.

Report.—A varied exhibit in styles and sizes; commended for good construction combined with economy in cost.

4. F. P. Stone, Chicago, Ill., U. S.

WAGON.

Report.—Commended for good workmanship.

5. Jacob Rech, Philadelphia, Pa., U. S.

MILK WAGON.

Report.—Commended for skillful construction and substantial workmanship.

6. James R. Hill & Co., Concord, N. H., U. S.

CONCORD COLLARS.

Report.—Commended for excellent workmanship and material and fitness for the purpose intended.

7. New Haven Folding Chair Co., New Haven, Conn., U. S.

REVERSIBLE-BODY CHILD'S CARRIAGE.

Report.—Commended for good construction and adaptation to the purpose intended.

8. Moline Wagon Co., Moline, Ill., U. S.

FARM WAGONS.

Report.—Commended for good construction and workmanship.

9. J. B. Sammis & Co., New York, N. Y., U. S.

EXCELSIOR ELASTIC HUB.

Report.—Commended as an important and valuable improvement for carriages and other wheeled vehicles, imparting greater ease in riding by lessening the vibration, with great economy in wear and tear.

10. William & Harvey Rowland, Philadelphia, Pa., U. S.

CARRIAGE SPRINGS AND IRON IN SHAPES.

Report.—Commended as a large and varied exhibit, showing excellent material of their own manufacture combined with good and substantial workmanship.

11. Rubber Step Manufacturing Co., Boston, Mass., U. S.

RUBBER-COVERED CARRIAGE STEPS.

Report.—Commended for good construction and fitness for purpose intended.

12. J. T. Smith & Co., Boston, Mass., U. S.

HACK SLEIGH.

Report.—Commended for good design and adaptation to the purpose intended.

13. C. Cowles & Co., New Haven, Conn., U. S.

CARRIAGE TRIMMINGS.

Report.—A good exhibit of carriage trimmings in metals, of excellent styles and finish.

14. Joseph Russell, Portland, Me., U. S.

SLEIGH.

Report.—Commended for good general work.

15. C. W. F. Dare, New York, N. Y., U. S.

CHILD'S CARRIAGE.

Report.—Commended for great excellence in design, construction, and finish.

16. Frederick Seidle, Mechanicsburg, Pa., U. S.

FINISHED SHAFTS AND POLES.

Report.—Commended for good material and workmanship.

17. Pennsylvania Axle Works (Advena & Heald), Philadelphia, Pa., U. S.

WAGON AXLES.

Report.—Commended for good material and workmanship and fitness for purpose intended.

18. Thomas Skelly, Philadelphia, Pa., U. S.

WROUGHT-IRON HAND-MADE CARRIAGE BOLTS.

Report.—Commended for the excellent material used, uniformity in fitting the nuts together, and for superior finish and strength.

19. Peter Barry, New York, N. Y., U. S.

HERALDRY PAINTING.

Report.—Commended as displaying highly artistic excellence in drawing and coloring, and a thorough knowledge of heraldic rules.

20. Sebastian Armbruster, Vienna, Austria.

LANDAU.

Report.—Commended for good workmanship.

21. J. Enders & Co., Louisville, Ky., U. S.

BUGGY.

Report.—Commended for general good workmanship and finish.

22. J. W. Gosling, Cincinnati, Ohio, U. S.

CARRIAGES.

Report.—Commended for general good workmanship.

23. Frederick Oppenheim, San Francisco, Cal., U. S.

A SINGLE AND DOUBLE BUGGY.

Report.—Commended for ingenious and novel arrangement of seats.

24. Renick, Curtis, & Co., Greencastle, Ind., U. S.

CARRIAGE (COMBINED SLIDE AND JUMP SEAT).

Report.—Commended for novelty and ingenuity in the arrangement of seats.

25. John McDermott & Brother, Washington, D. C., U. S.

TOP BUGGY.

Report.—Commended for good workmanship.

26. Sargent & Ham, Boston, Mass., U. S.

EXTENSION TOP PHAETON.

Report.—Commended for good style, excellent material, workmanship, general finish, and adaptation to purpose intended.

27. Chev. Alessandro Locati, Turin, Italy.

CABS.

Report.—Commended for good workmanship.

28. Daniel Conboy, Uxbridge, Ontario, Canada.

SLEIGH.

Report.—Commended for originality and good workmanship.

29. Jacob Lohner & Co., Vienna, Austria.

PHAETON, OR GENT'S DRIVING CARRIAGE.

Report.—Commended as good in design and construction.

SIGNING JUDGE OF SUPPLEMENT TO GROUP XVII.

The figures annexed to the name of the Judge indicate the reports written by him.

B. F. BRITTON, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29.

United States Centennial Commission.

INTERNATIONAL EXHIBITION,
1876.

REPORTS AND AWARDS

GROUP XVIII.

EDITED BY
FRANCIS A. WALKER,
CHIEF OF THE BUREAU OF AWARDS.

PHILADELPHIA:
J. B. LIPPINCOTT & CO.
1877.

Entered, according to Act of Congress, in the year 1876, by the
CENTENNIAL BOARD OF FINANCE,
In the Office of the Librarian of Congress at Washington.

SYSTEM OF AWARDS

[*Extract from Circular of April 8, 1876.*]

Awards shall be based upon written reports attested by the signatures of their authors.

The Judges will be selected for their known qualifications and character, and will be experts in departments to which they will be respectively assigned. The foreign members of this body will be appointed by the Commission of each country and in conformity with the distribution and allotment to each, which will be hereafter announced. The Judges from the United States will be appointed by the Centennial Commission.

* * * * *

Reports and awards shall be based upon inherent and comparative merit. The elements of merit shall be held to include considerations relating to originality, invention, discovery, utility, quality, skill, workmanship, fitness for the purposes intended, adaptation to public wants, economy and cost.

Each report will be delivered to the Centennial Commission as soon as completed, for final award and publication.

Awards will be finally decreed by the United States Centennial Commission, in compliance with the Act of Congress, and will consist of a diploma with a uniform Bronze Medal, and a special report of the Judges on the subject of the Award.

Each exhibitor will have the right to produce and publish the report awarded to him, but the United States Centennial Commission reserves the right to publish and dispose of all reports in the manner it thinks best for public information, and also to embody and distribute the reports as records of the Exhibition.

ORGANIZATION AND DUTIES OF THE JUDGES.

[*Extract from Circular of May 1, 1876.*]

Two hundred and fifty Judges have been appointed to make such reports, one-half of whom are foreigners and one-half citizens of the United States. They have been selected for their known qualifications and character, and are presumed to be experts in the Groups to which they have been respectively assigned. The foreign members of this body have been appointed

by the Commission of each country, in conformity with the distribution and allotment to each, adopted by the United States Centennial Commission. The Judges from the United States have been appointed by the Centennial Commission.

To facilitate the examination by the Judges of the articles exhibited, they have been classified in Groups. To each of these Groups a competent number of Judges (Foreign and American) has been assigned by the United States Centennial Commission. Besides these, certain objects in the Departments of Agriculture and Horticulture, which will form temporary exhibitions, have been arranged in special Groups, and Judges will be assigned to them hereafter.

The Judges will meet for organization on May 24, at 12 M., at the Judges' Pavilion. They will enter upon the work of examination with as little delay as practicable, and will recommend awards without regard to the nationality of the exhibitor.

The Judges assigned to each Group will choose from among themselves a Chairman and a Secretary. They must keep regular minutes of their proceedings. Reports recommending awards shall be made and signed by a Judge in each Group, stating the grounds of the proposed award, and such reports shall be accepted, and the acceptance signed, by a majority of the Judges in such Group.

The reports of the Judges recommending awards based on the standards of merit referred to in the foregoing System of Awards, must be returned to the Chief of the Bureau of Awards not later than July 31, to be transmitted by him to the Centennial Commission.

Awards will be finally decreed by the United States Centennial Commission, in compliance with the Act of Congress of June 1, 1872, and will consist of a special report of the Judges on the subject of the Award, together with a Diploma and a uniform Bronze Medal.

Upon matters not submitted for competitive trial, and upon such others as may be named by the Commission, the Judges will prepare reports showing the progress made during the past hundred years.

Vacancies in the corps of Judges will be filled by the authority which made the original appointment.

No exhibitor can be a Judge in the Group in which he exhibits.

An exhibitor, who is not the manufacturer or producer of the article exhibited, shall not be entitled to an award.

The Chief of the Bureau of Awards will be the representative of the United States Centennial Commission in its relations to the Judges. Upon request, he will decide all questions which may arise during their proceedings in regard to the interpretation and application of the rules adopted by the Commission relating to awards, subject to an appeal to the Commission.

A. T. GOSHORN,
Director-General.

[*Extract from Director-General's Address to Judges, May 24, 1876.*]

“The method of initiating awards which we have adopted differs in some respects from that pursued in previous exhibitions. In place of the anonymous verdict of a jury, we have substituted the written opinion of a Judge. On this basis awards will carry the weight and guarantees due to individual personal character, ability, and attainments, and to this extent their reliability and value will be increased. It is not expected that you will shower awards indiscriminately upon the products in this vast collection. You may possibly find a large proportion in no way raised above the dead level, nor deserving of particular notice. The standard above which particular merit worthy of distinction begins is for you to determine. In this regard I have only to express the desire of the Centennial Commission, that you should do this with absolute freedom, and when you meet with a product which you consider worthy of an award, we desire you to say, in as few words as you may deem suitable, why you think so.

“This, gentlemen, is all we ask of you in the Departments of Awards. Opinions thus expressed will indicate the inherent and comparative merits, qualities, and adaptations of the products,—information which the public most desires.

“Elaborate general reports and voluminous essays, though of great value as sources of general information, give little aid in determining the reliable or intrinsic merits of particular, individual products.

“The regulations which have been published divide the work of awards into three parts:

“1st. The individual work of the Judges.

“2d. The collective work of the groups of Judges.

“3d. The final decisions of the United States Centennial Commission in conformity with the acts of Congress.

“Each award will thus pass three ordeals, which, doubtless, will be ample and satisfactory.”

GROUP XVIII.

JUDGES.

AMERICAN.

FELICIAN SLATAPER, Chief Engineer,
Penna. Co., Pittsburg, Pa.

T. A. MORRIS, Indianapolis, Ind.

ROBERT E. RICKER, Elizabeth, N. J.

FOREIGN.

DOUGLAS GALTON, R.E., Great Britain.

ERNST PONTZEN, C.E., Austria.

E. SCHARR, C.E., Belgium.

GROUP XVIII.

RAILWAY PLANT, ROLLING STOCK, AND APPARATUS; ROAD ENGINES.

CLASS 570.—Locomotives, models, drawings, plans, etc.

CLASS 571.—Carriages, wagons, trucks, cars, etc.
Snow-plows.

CLASS 572.—Brakes, buffers, couplings.

CLASS 573.—Wheels, tires, axles, bearings, springs, etc.

CLASS 574.—Permanent way, ties, chairs, switches, etc.

CLASS 575.—Station arrangements, water-cranes, turn-tables.
Railway signals.

CLASS 576.—Miscellaneous locomotive attachments.

CLASS 577.—Street railways and cars.
Road and traction engines, etc.

GENERAL REPORT
OF THE
JUDGES OF GROUP XVIII.

INTERNATIONAL EXHIBITION,
Philadelphia, 1876.

PROF. FRANCIS A. WALKER, *Chief of Bureau of Awards:*

SIR,—Herewith I transmit the reports of the Judges of Group XVIII.

Respectfully yours,
FELICIAN SLATAPER,
Secretary.

GROUP XVIII.

RAILWAY-PLANT ROLLING-STOCK AND APPARATUS; ROAD ENGINES.

EXTRACT FROM THE BRITISH REPORT ON RAILWAY APPLIANCES.

BY DOUGLAS GALTON.

The railway appliances exhibited at the Centennial Exhibition were principally derived from the United States and Canada. There were a limited number of foreign exhibits of peculiar merit, such as the signaling arrangements sent from Great Britain, the tires and axles from Sweden, and the buffers, couplings, and wheels from Belgium; but the main features of the exhibition were derived from American sources. In this point of view the Philadelphia Exhibition possesses peculiar interest for England, in that it brings into prominence those features in which the American system differs from our own.

It is just twenty years since I made a report to the Board of Trade upon the railway system of the United States. This report affords, even after the lapse of so many years, an accurate representation of the American railway system. The improvements and developments which have taken place in the system since that time have closely followed the lines which I then pointed out.

The American railway system is the offspring of totally different wants from those experienced in England. In Europe capital was plentiful; the populations to be accommodated were already gathered into fixed localities; good roads and canals existed; so that the railway was originally looked upon rather as a means of diminishing distance by the use of high speeds than as the universal road for traffic. In America, on the other hand, the railway has been the pioneer road of the country, and the sole means of communication. It has opened out new districts to the settlers, and has caused the growth of new towns, and thus developed the country with immense rapidity.

The construction of the railway thus led to the absorption of a large capital for developing the country through which it passed; and the high return which such expenditure afforded prevented the investment in a railway of more capital than was sufficient to enable it to perform the work immediately required of it. Thus, while the first cost of a railway was small, a considerable expenditure had to be incurred in perfecting the line, in proportion as the requirements of the population it had attracted to its vicinity increased. In a new country certainty of communication is of far more importance than speed, and the rough standard which prevailed in the pioneer lines of railway in the United States entirely answered its object.

The more perfected system now at work in the Eastern States has grown out of this rough standard, and the Philadelphia Exhibition afforded us a means of tracing out how the improvements which have taken place have followed chiefly in those original lines. Thus the improvements in railways have been, in the material matters of construction of the permanent way, in the engines, and in the comfort of the passengers in the cars, rather than in stations.

The early American railways had to be made out of such material as lay to hand, and out of such money as could be brought together. The sleepers were laid on the soils, there was little or no ballast, sharp curves and steep gradients were the rule, in order to avoid cuttings by following the sinuosities of the ground; and therefore a short, rigid wheel-base became imperative in the rolling-stock. To facilitate supervision, and to meet the democratic tendencies of the country, the pattern of the car followed that of the saloon of a steamboat, instead of being a development of the body of a stage-coach as English railway-carriages were. The cars are coupled in the central line of the car, so that they may accommodate themselves to sharp curves. The entrance to the car is by means of a short platform with descending steps at the end, which render station platforms unnecessary. Moreover, the body of the car contains conveniences, so that the construction of the expensive conveniences which are erected at English stations are not required in America.

In the arrangements of the station, moreover, the signaling has always been in a more primitive condition than in England. Until recently there had not been such a traffic as would require or justify the expensive signal arrangements employed in England. More responsibility seems to be thrown on the engine-driver or engineer, and therefore the direction of improvement appears to have rather lain in that of perfecting the train appliances, over which the engineer has control, than in developing the accessories to safety on the line

itself, which tend to diminish the responsibility of the officer in charge of the train.

There are so many points of interest connected with the railway system of the United States, apart from the mere mechanical problem which the Exhibition set before us, that I think I shall better fulfill the object of this report by limiting my account of the exhibits to those which displayed peculiar qualities, in order to afford space for a brief account of some of the more general problems which have arisen in the American railway system.

PERMANENT WAY.—The Pennsylvania Railroad Company exhibited a section of their standard track.

The main feature of the permanent way is in the shape of the head of the rail, the form of splice for the joints, the large number of sleepers, and the arrangement of the ballast. The rails are steel, of the Vignoles pattern. They are fished at the joints. There are two patterns of rails,—one of 60 pounds, the other of 67 pounds per yard. The 60-pound rail is $4\frac{1}{4}$ inches deep, and the 67-pound rail $4\frac{1}{2}$ inches. The head of the 60-pound rail is $1\frac{3}{8}$ inches deep; the head of the 67-pound rail is $1\frac{1}{2}$ inches deep. The splices are 2 feet in length; they are held by 4 bolts,—2 on each side of the joint. The outside splice has a tongue, passing over the flange of the rail and resting on the sleepers, to which it is spiked. The joint is suspended midway between two sleepers, placed so as to be 10 inches apart between the edges of the adjacent surfaces. In winter $\frac{5}{16}$ inch, and in summer $\frac{1}{16}$ inch, are left between the ends of the rails to allow for expansion. There are 16 sleepers, 8 feet 6 inches long 7 inches deep by 8 inches wide, to each 30-foot rail; the sleepers at the joints being placed 10 inches apart, and the others being evenly spaced between, but so that no sleepers should ever be more than 2 feet from centre to centre. The rails are spiked to each tie, both on the inside and outside.

Great care is taken to obtain an even bearing surface for the ties, which are not to be notched, but, if twisted, to be straightened with the adze. The subgrade is 31 feet 4 inches wide for the double road, and is formed with a slope from the centre towards each side, at a slope of 1 in 20. The ballast is laid to a depth of not less than 12 inches under the sleepers, and is filled up evenly between, but not above the tops of the ties, and at the outer end sloped off to the subgrade. Where stone ballast is used it is broken evenly, and not larger than a cube that would pass through a two-and-a-half-inch ring. With double tracks, coarse, large stones are placed in the bottom to provide for drainage, but care is taken to keep the coarse stones away from the ends of the ties.

This road, as exhibited, and for which an award was given, is the road in use over a large section of the Pennsylvania Railroad.

It will be seen that this form of permanent way depends for its solidity mainly upon the large number of sleepers. The surface occupied by timber is nearly as large as that occupied by ballast. Therefore a lighter rail can be used than in England, and so long as timber continues cheap this permanent way will hold its own. But the destruction of forests in recent years has been so great that this must soon cease. Another object attained by this permanent way is that water drains off rapidly,—a great matter in the hard frosts to which American roads are subject.

A large amount of ingenuity is expended in the United States upon nut-locks,—*i. g.*, means for preventing the nuts for securing fish-plates from becoming loose. None have as yet been found of such practical convenience as to obtain universal adoption; nor can it be expected that, with the forces always at work on a railway, anything can be devised which will do away with the necessity for frequent inspection.

There were some exhibits of crossings which merit notice; a chilled cast-iron crossing was exhibited by the Ankarsrums works in Sweden for durability, which has been at the entrance to a station since 1869, and showed scarcely any signs of wear. Elastic frogs and crossings were also exhibited,—*i. e.*, with a layer of caoutchouc under the iron or steel frog to prevent the jar; but they appeared to show ingenuity rather than practical merit. The switches and points on American railways are universally of the pattern we term contraction points. The rule on all American railways is to keep all the switches leading off a main line fastened in position by a padlock. In England this form of switch is entirely discarded. The perfection of the points which we use has itself opened them to many serious elements of danger, from the possibility of some foreign matter preventing the points from closing.

In the Philadelphia Exhibition, Messrs. Brierley, Sons, & Reynolds exhibited a method for the mechanical removal of such obstruction by means of a plate, which lies on the level of the surface of the rail between the points when they are open, and is dropped below the rails as the points close. Messrs. Saxby & Farmer and Messrs. Brierley, Sons, & Reynolds both exhibited a means of locking the points in position. The former pass a bolt through the centre of the bar which connects the pair of points, while Messrs. Brierley, Sons, & Reynolds fix the point against the rail by means of a bolt moved up from below. The latter is the more reliable arrangement.

When one looks at the simplicity of the American system of the

old contractor's point, it would seem that if as much ingenuity had been bestowed upon a means for locking them when they have been moved into position as has been bestowed upon the points which we have adopted, they would be safer than ours from their simplicity.

The modification of the form of switch which is most deserving of notice, as presenting features of peculiar novelty, is the Wharton-switch. The principle of this switch is that of carrying the train off the main line on to a siding without any break in the continuity of the main-line rails. This is effected in the following manner: The inner switch-rail is connected with a movable guard-rail. This connected switch- and guard-rail in section is shaped like a U, and one side terminates in a point, which laps under the main rail in the same way in which our points do, and this guides the wheel, as our points also do, away from the main rail. This throws the opposite wheel close against the other main rail, and causes the outer part of the tread of the wheel to pass on to the outer switch-rail from the place where the tread of the wheel there gets a bearing on the outer switch-rail. The guard-rail and the switch-rail are gradually inclined upwards; by this means they raise the wheels sufficiently to enable the flange to pass over the top of the main rail into the siding, instead of passing through a slit in the rail, as is the case with our points and crossings. I saw this arrangement in practical working on railways, and it gives great satisfaction. The rails were lower and somewhat narrower on the top table than ours, and the tread of the wheels somewhat broader. The success of this form of switch depends on the outer portion of the tread of the wheel obtaining a good footing on the outer switch-rail.

In connection with permanent way, I should mention that there were several "car replacers" exhibited for restoring cars to the rails after accidents from trains leaving the rails. This would seem to be an index of the frequency of such accidents.

The signaling arrangements on the American railways have not aspired to the perfection to which they have been brought on our railway system, and consequently the only signaling exhibits of notable value were those of the English exhibitors, viz., Messrs. Saxby & Farmer and Messrs. Brierley, Sons, & Reynolds, both of which are in use in England, and need no description here. There were three or four American exhibits of level-crossing gates, but none of special merit.

ROLLING-STOCK.—The exhibits of appliances suited for rolling-stock were numerous, and some were of much merit. The pattern of the cars on American railways is essentially different from English

cars, but it is sufficiently well known to render further reference to it unnecessary here. The long distances to be traveled on American lines have tended to convert the car into a traveling hotel, and the completeness of the accommodation afforded for this purpose was well exemplified in the exhibits of the Pullman Car Company. It is unnecessary to give a detailed description of these cars here, as their general construction is well known in England, where, however, the shorter distances traveled over render these cars comparatively unnecessary. They could, however, be very advantageously applied for the journey between London and the north of Scotland, and would be peculiarly advantageous for through trains on the Continent, such as those traveling from Calais, Brussels, and Paris to Berlin, Vienna, Florence, Rome, Brindisi, and even those to Marseilles and the Riviera.

The exhibits of appliances for cars fall under the head of car-fittings, stoves, couplings, springs, car-wheels. In connection with these must be mentioned tires and axles (which, however, apply equally to locomotive-engines), and brakes.

The exhibits of couplings were numerous. In those for the passenger-cars there was nothing to supersede the usual coupling, now adopted in the United States, termed the Miller's platform and coupling, which consists of a compression buffer and coupling. It is self-coupling when the cars are run against each other, and holds the platforms in position close to each other. In passenger-cars, however, the train servants stand on the platform between the cars, and with full access to the coupling, and thus need incur no risk of being injured in the act of coupling. With the freight-cars it is different. In these the space between the cars is frequently so restricted that, as the coupling is in the centre, risk must be incurred by the train servants. Several exhibits were devised to meet this, chiefly by lever movements, with handles, to be worked from the side of the car, so as to avoid the necessity of passing between the cars; but in no instance was the invention of such merit as to obtain an award.

Of the car-fittings, those exhibited by Messrs. Peet were deserving of much commendation, for the high finish and excellence of workmanship. Messrs. Cremer's exhibits in this line also deserve commendation.

In connection with car-fittings should be mentioned the ingenious apparatus furnished to the conductor for punching tickets, with a bell to strike each time it is used, the passengers being requested to notice that the bell is struck when his ticket is taken and punched. The number of contrivances in use (more frequently in street-cars than in

railways) for checking the receipts of the conductors is also remarkable. These inventions are an index of the difficulties incurred by the transportation companies in obtaining an accurate account of their receipts. It is no doubt incidental to the necessity of allowing the conductors to issue as well as to collect the tickets, a system which is a necessity of many American railways, because the traffic of many of the smaller stations would not justify the maintenance of a staff of officials; consequently the smaller stations are mainly places to take up and set down passengers or freights; the primary work not performed by sender or receiver being done by the servants of the company in the train.

Among the car-fittings I would mention a very simple spring-cushion, the spring being a ribbon of steel, bent into an elliptical form and fixed to the wooden frame on each side at the end of the longer axis of the ellipse. These were exhibited by Messrs. Cobb, of Wilmington, Delaware, and the Elliptic Car-Spring Company, of Cincinnati, Ohio.

There were several methods of warming cars exhibited. Of course, the arrangements for heating applicable to the large saloon-cars are different from what our separate carriages require. There were, however, some, by means of lamps placed under the car, which might be applied to either arrangement of carriage. But the carrying of fire in any form in a train must always be more or less a source of danger in case of collisions or of cars leaving the rails. The form of heater which appears to have obtained the greatest favor in America is what is termed the Baker heater, of which the following is the description: the heat is applied to the car by means of hot-water pipes led round the car on the floor-level, with bends to carry the pipes under each row of seats; the water is heated by means of a coiled part of the pipe, which is passed through a small circular stove, coiling a portion of the pipe and passing this coiled portion through a circular iron stove; the fire-box of this stove is of strong iron, and is provided with a grated lid, with a latch, to be opened for feeding the fire, but which cannot become opened by any violence or by an upset. The fire-box is, moreover, contained in a second strong covering of iron, which terminates in the chimney. No instance is recorded of fire having occurred in train accidents where these stoves have been used. For the circulation, both ends of the pipe terminate in a close cylindrical cistern, placed on the roof of the car, to which the water is applied by means of a funnel-pipe, which also acts as a gauge of the level of the water. A safety-valve, weighted to 150 pounds pressure, and an indicator-dial are provided. The safety-valve is formed of a compres-

sible india-rubber ball, as a metal-seated valve is inapplicable, owing to the crystals of salt which form after "blowing off," and prevent the valve from shutting tightly. The india-rubber ball overcomes this difficulty. The liquid used is a saturated solution of salt-water, and on first filling great care must be taken by repeated applications of heat to expel all the air. This solution does not freeze at any ordinary low temperatures. The average allowance of heating surface for an ordinary passenger-car is stated to be four feet of $1\frac{1}{4}$ pipe per passenger. A large amount is required for compartment cars, and the distribution of the pipe varies according to the position of the seats, a smaller amount of surface being allotted to the seats over the flow-pipe where it leaves the stove, and a larger amount to those over the colder parts of the return-pipe.

There were several exhibits of springs. It seems that the caoutchouc springs are not liked in America. Either from the difficulty of obtaining good material, or otherwise, these springs become hard and useless in severe frosts. Steel springs are therefore resorted to. The forms which are most noticeable from their novelty are the volute springs in nests of four or five.

Cast-iron chilled car-wheels are in general use in the United States, and the exhibit of car-wheels was especially prominent. I will briefly describe the cast-iron wheels, and then notice such of the exhibits of other forms as appeared to possess merit. The first chilled wheels were made in 1832, but they were made with flat spokes, and the central part cast with openings to prevent the fracture of the central part by shrinking. The first plate wheel which had any success was made by Mr. Lobdell in 1838. The wheel was cast in one piece, the plates or disks were convex on the outside. In 1848 an annealing process was patented by Messrs. Whitney, and has been generally adopted since.

The principal exhibitors in the United States were Messrs. Lobdell, Mr. Whitney, the Hamilton Wheel Foundry, the Taylor Wheel Foundry, the Pennsylvania Railroad, and Mr. W. G. Hamilton, who exhibited wheels made by his mixture of irons. There were several Canadian exhibitors of wheels, notably Messrs. Macdougall & Co., Montreal, and the Toronto Wheel Foundry.

The following is a brief description of the peculiarities of cast-iron wheel-making. The material used is a proportion of cold-blast charcoal iron, generally of the Salisbury ores, and some warm-blast (*i.e.*, made with a blast of about 500°), principally from Baltimore ores; a limited quantity of selected old wheels are added in proportion to the quality of the iron. This is melted in a cupola furnace

and run into pigs, which are inspected and stored for remelting. The remelted iron is run into the chilled moulds, and as soon as the iron has solidified the wheels are removed and placed in an annealing-pit, where they are left to cool for three or four days, the object being to produce a perfect chill of the outer surface of the tread of the wheel and of the flange. Mr. Hamilton's process has been devised to meet what he considers will be a great difficulty soon, viz., the insufficient quantity of the Salisbury iron to meet the large demand for wheels, coupled with the probably diminished production of charcoal iron from the great destruction of forests which is taking place all over the country. The following short statement will explain this: The production of car-wheels in 1876 was about 500,000 wheels, representing a daily requirement of 1250 tons of iron, of which 300 tons would be obtained from remelting old car-wheels, and 950 tons from new iron, or a total yearly requirement of, say 290,000 tons. The total yield of charcoal iron in 1873 was 574,720 tons, as follows:

	Tons.		Tons.
Maine	780	Alabama	22,283
Vermont	3,100	Texas	280
Massachusetts	15,704	West Virginia	1,950
Connecticut	26,977	Kentucky	42,219
New York	29,327	Tennessee	34,532
Pennsylvania	45,854	Ohio	100,498
Maryland	30,318	Michigan	113,475
Virginia	20,075	Wisconsin	38,880
North Carolina	1,432	Missouri	39,536
Georgia	7,591		

Of the above the yield of Salisbury iron, calling by that name all made in Massachusetts, Connecticut, and part of New York, was:

	Tons.
Massachusetts	15,704
Connecticut	26,977
New York (say)	5,000
	<hr/>
	47,681

Thus the Salisbury iron forms only 16 per cent. of the new iron required for car-wheels, and the whole production of charcoal iron was only double that required for car-wheels alone in a year of small production, of which the production of Pennsylvania is considerable.

Mr. Hamilton, by adding a proportion of steel, is enabled to use non-chilling irons for car-wheels, such as low grade charcoal (warm-blast) irons, anthracite, coke and raw coal irons. The mixture he adopts is as follows:

	Per Cent.
Charcoal iron	24
Hot-blast coke iron	7
Anthracite	25
Old wheels and scrap	34
Old steel rails	10
	—
	100

The results he exhibited, especially in the factory of Altoona, appeared very satisfactory.

The duration of car-wheels in the United States was given at from 50,000 to 60,000 miles. They can then be turned up and run a further mileage. The wear of the wheels takes place more rapidly when they are not exactly circular, and to meet this Messrs. Lobdell have taken steps to turn up wheels before sending them out. The price is enhanced, but they guarantee 90,000 miles.

The exhibits of car-wheels from the Dominion of Canada were satisfactory; the prices furnished by Harris & Co., of St. John, New Brunswick, were, for 30-inch wheel, \$12.75; 33-inch wheel, \$16.

The failure of chilled iron car-wheels may occur:

1st. From the chill failing,—*e.g.*, pieces on the tread or flange shell out, or the tread becoming comby or seamed.

2d. From wear on rail, such as worn flange, worn flat, worn hollow at flange, worn hollow on tread.

3d. From being broken, such as the wheel having burst, or the flange or rim being broken, or the plate being cracked.

4th. From wearing flat from sliding out or cracks, but it is said that they never burst or break in pieces in running.

The other notable exhibits of wheels were from Sweden, Belgium, France, and Germany, the latter by Krupp. The chilled cast-iron wheels and axles of Carl Ekman, of Sweden, were remarkable for economy of production and excellence.

The Sandvikens Steel Works and the Surahammars Bruk Works both exhibited wheels and axles scarcely worn which had run over 200,000 miles.

The wheels of L'Atelier de la Dyle were noteworthy, as also those of the Société de la Providence, both in Belgium.

The latter wheels are made solid, of wrought-iron, by hydraulic pressure.

The wheels of Brunon Frères, Rive-de-Gier, France, forged by hydraulic pressure, also deserve mention; as also the wheels exhibited by Lucien Arbel, from the same locality.

As an index that the cast-iron wheel is not affording full satisfaction

in America may be taken the fact that there were several exhibits of other forms of wheels, in which elasticity was sought to be introduced, and notably of wheels with steel tires.

The exhibit of this nature which seemed to possess most merit was that of wheels of compressed paper. The central portion of the wheel is entirely of paper, compressed by hydraulic machinery to the consistence of wood, but without the liability to split, which wood more or less has; the hub and the tires are of steel. These wheels are run under the Pullman cars, and a wheel was exhibited which had run for eight years under a Pullman car, and a distance of 302,900 miles, the tire of which showed very small marks of wear. The duration was attributed to the elasticity of the material. The cost of these wheels was stated to be, for a 30-inch and a 33-inch wheel, \$60 to \$70; for a 42-inch wheel, \$80.

Another form of wheel in which durability was sought in elasticity was a form of locomotive driving-wheel, to which steel tires were fixed, with blocks of hickory between the felloe and the tire, so as just to relieve the tire from resting on the iron rim. This class of wheel is stated to have been in use some years, and to have given very favorable results. There were several axles exhibited which had for their object to allow the wheels in each pair of wheels to revolve independently of each other. Of these there were three which deserve notice. One by S. L. Harrison, which had run for $8\frac{1}{2}$ months on street-cars in San Francisco. In this, each wheel is fixed to a sheath, which extends to the centre of the axle, and which revolves with the wheel to which it is attached upon the axle. The second was by Mr. Anchinlos, manager of the Jackson & Sharp Company. In this case the axle was divided in the middle, and held in place by a sleeve fitted on in the centre about two feet long, in which the parts could revolve separately. In this case each wheel revolves with its own half of the axle. The third is the Miltimore axle. These were applied to one of the trains running in the Centennial grounds, and with a notable diminution of the friction in passing round the very sharp curves on this railway. In the construction of the Miltimore axle, the wheel is attached to a sleeve which revolves round the axle upon which the car rests; the sleeve being kept in place by the axle-boxes, which are fixed to the main axle.

The brakes on American railways have been perfected to a far greater extent than in England. This appears to have arisen from the necessity for the rapid stopping of trains, introduced by the less secure condition of fencing on American railways, and the greater prevalence of single lines.

It would seem more to be recognized as an axiom on American railways,—

1st. That the engineer shall have complete control over the application of brake-power to all the wheels of the train.

2d. That in case of the accidental fracture of couplings, the detached cars shall be at once brought to rest by the action of the brakes attached to them.

The Westinghouse brake appears to have obtained the confidence of the American railway managers, and it is applied very extensively on American railways. The Westinghouse Air Brake Company, of Pittsburgh, Pennsylvania, have bought the patent of Smith's vacuum brake. They state that they apply this latter occasionally as being less expensive, where rapidity of action is not of paramount importance; but for all passenger-trains they recommend their own automatic brake. The difference between the two broadly stated is, that in the Smith's vacuum brake the application of the brake depends upon the vacuum in the pipes. In the Westinghouse automatic brake, the air in the pipes is pumped in continually under pressure, and the brakes are applied by a diminution of the pressure.

The Westinghouse Company have placed their brake prominently before the English public, so that a description of the apparatus now is unnecessary. I would, however, observe that Mr. Steele has patented a brake in England which is on the same principle as the Westinghouse automatic brake, for which he claims a greater simplicity of the parts. This brake was fitted to certain carriages, to be experimented on by the Royal Commission on Railway Accidents; but Mr. Steele states that the train was not ready in time to obtain conclusive results. In the absence of more complete information, no opinion can be expressed now, except that undoubtedly the Westinghouse brake has been proved to be eminently successful on the American railways.

Among the other brakes exhibited were Henderson's hydraulic brake. This was simple in construction and operation. The power is derived from a small portion of the steam from the boiler, applied through a double-acting steam-cylinder, to work a small hydraulic press. The water-pressure is transferred through pipes to pressure-boxes, of which there is one attached to one of the brake-beams on each truck. An air-cushion is provided above the press-piston to prevent striking the head when coming back light. The press receives water from either the tender or from a special tank through a check-valve; the feed is self-regulating, any excess of water being returned through a small pipe to the tank. For low temperature, a mixture of equal parts of glycerine and water is used, which is safe

to 24° of Fahrenheit below zero. The pressure-boxes are of cast-iron, bolted together, embracing a disk-shaped, flexible diaphragm of india-rubber. A ram is fitted to the hollow of the diaphragm, two iron rods connecting the end of the ram to the opposite brake-beam. When pressure is applied, the diaphragm moves out in one direction and the pressure-box in the other, thus bringing the opposite brake-beams to press against the wheels. The connections between the cars are made by means of flexible hose furnished with hydraulic couplings, which couple and uncouple without waste.

The Loughbridge air-brake, in use on the Baltimore & Ohio Railroad, was not exhibited. The particulars of an experiment made with it showed that a train of 10 cars, weighing, with locomotive, 230 tons, traveling at a speed of 42.6 miles per hour, on a straight and level grade, was stopped in 16 seconds in a space of 196 yards.

LOCOMOTIVES.—The only exhibit of a locomotive which was not of United States manufacture was a locomotive from Sweden, for drawing heavy weights on a narrow gauge, it being adapted for the three-foot gauge. The peculiar feature of this class of exhibits, however, was the exhibit of American locomotives.

The following are the more remarkable of these exhibits:—It may be mentioned as a curiosity that the Camden & Amboy Railroad Company exhibited the "John Bull" engine, built by George and Robert Stephenson, of Newcastle-on-Tyne, for the Camden & Amboy Rail & Tramway Company, in the year 1831, and which commenced running in September of that year. The cylinders are 9 inches by 20 inches stroke; the driving-wheels 4 feet 6 inches diameter, with iron hubs, wooden spokes, and wrought-iron tires. Its weight is 10 tons. It was in use from 1831 till 1861.

Of the exhibitors of the latest style of modern American engines, those most noteworthy were the Baldwin Locomotive Works, of Philadelphia, Pennsylvania, owned by Messrs. Burnham, Parry, & Williams, and managed by their able and enterprising partner, Dr. Williams. They exhibited five locomotives. The following tables show the particulars of the exhibit of the Baldwin Locomotive Works, of the light locomotive of Porter, Bell, & Co., of Pittsburgh, Pennsylvania, and of the engine of the Dickson Manufacturing Company, of Scranton, Pennsylvania.

EXHIBIT OF BALDWIN LOCOMOTIVE COMPANY.										PORTER, BELL, & CO.		DICKSON MANUFACTURING COMPANY.	
CYLINDERS.	Gauge, 4 ft. 8½ ins. Consolidation Pattern. Freight.	Gauge, 4 ft. 8½ ins. Consolidation Pattern. Freight.	Gauge, 4 ft. 8½ ins. Mogul Pattern. Freight.	Gauge, 4 ft. 8½ ins. American Pattern. Passenger.	Gauge, 4 ft. 8½ ins. American Pattern. Passenger.	Gauge, 3 ft. Passenger. 4 wheels, coupled.	Gauge, 3 ft. Mogul Pattern. Freight. 6 wheels, coupled.	Gauge, 4 ft. 8½ ins. 2 wheels, coupled.	Gauge, 3 ft. 3 wheels, coupled.	Gauge, 3 ft. 2 wheels, coupled.			
	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.			
	1 8	1 8	1 6	1 5	1 5	0 11	0 11	0 17	0 11	0 9			
	2 0	2 0	2 0	1 10	2 0	0 16	0 16	0 24	0 16	0 12			
	1 4	1 5½	1 4	1 3	1 4	0 11	0 11	1 4	0 9½	0 8			
	1 1½	1 1½	1 1½	1 1½	1 1½	0 11	0 11	0 11½	0 1	0 16			
	0 2½	0 2½	0 2½	0 2½	0 2½	0 11	0 11	0 2½ x 16	0 2 x 16	0 1½ x 6			
	0 5½	0 5	0 5½	0 5½	0 5½	0 11	0 11	0 5½	0 4½	0 3			
	0 0¼	0 0¼	0 0¼	0 0¼	0 0¼	0 11	0 11	0 0¼	0 0½	0 3½			
	0 0¾	0 0¾	0 0¾	0 0¾	0 0¾	0 11	0 11	0 0¾	0 0¾	0 3½			
Variable.	Double sq.	Double var.	Single high.	Double.									
WHEELS.													
Diameter of driving-wheels.....	4 2¾	4 2	4 6	5 2	5 2	40 to 44	36 to 40	5 7	3 6	2 5			
Diameter of truck-wheels.....	2 6	2 4	2 6	2 4	2 4	26 to 28	24 to 26	2 6	2 0				
Distance between centres of front and rear driving-wheels.....	14 9	13 8	15 0	8 6	8 6	ft. ins.	ft. ins.	8 0	6 8	4 6			
Total wheel-base of locomotive.....	22 10	21 6	22 8	22 5	22 5½	32 12	34 6	21 10	26 ft. 3 ins.	4 6			
Total wheel-base of locomotive and tender..	46 2	27 7	44 3	44 2½	44 3½	(39 ft. length over all, of engine and tender.)	(41 ft. length over all, of engine and tender.)	33 ft. 8½ ins. length over engine.	42 ft. 6½ ins. length over all, of engine and tender.	17 ft. 10½ ins. length of engine.			
Diameter of driving-axle journals.....	0 7	0 6½	0 8	0 7	0 7½			0 7	0 5	0 4½			
Length of driving-axle journals.....	0 8	0 7½	0 8	0 8	0 8½								
Diameter of main crank-pin bearing.....	0 5	0 4½	0 5	0 4½	0 5½								
Length of main crank-pin bearing.....	0 5	0 4½	0 5	0 4½	0 5½								

The other exhibitors were the apprentices of the Philadelphia & Reading Railroad, for the coal traffic of that line. The coal traffic is down-hill, on an easy gradient of 12 feet per mile; the engine brings down a load of 1060 tons, and takes back 405 tons of cars empty, at a speed for the down journey of 10 to 12 miles, and of 12 to 15 miles for the up journey; with a consumption of fuel of 70 pounds per mile for the down trip, and 98 pounds per mile for the up trip.

The Danforth Locomotive & Machine Company, of Paterson, New Jersey, exhibited a plantation-engine and a passenger-engine, which received an award. The Rogers Locomotive & Machine Works, of Paterson, New Jersey, also obtained an award.

The following remarks on these engines will enable an opinion to be formed of the merits of American engines as compared with those in use in England:

"The consolidation pattern, No. 1, has been used on the Lehigh Valley Railroad, over maximum grades of 126 feet per mile, with a maximum load of 35 loaded 4-wheel cars, which weigh 329 tons. On a grade of 76 feet per mile it draws 476 tons. The consumption of fuel is given at $3\frac{3}{4}$ tons daily. The No. 2 consolidation engine does the following:

	Number of Cars.	Total Weight, exclusive of Engines. Tons.	Maximum Grade.
Philadelphia & Columbia	35	734	40 per mile.
Columbia & Harrisburg	70	1470	Short grade of 30 feet.

"Average consumption of fuel, 42 pounds per car per mile on Philadelphia & Columbia division, and 27 pounds per car per mile on the Columbia & Harrisburg division. The passenger locomotive, American pattern, No. 2, travels between Harrisburg and Altoona, at 38 miles an hour, with a train weighing 171 tons, exclusive of engine, on the maximum grade of 21 feet per mile; the average consumption of fuel being about 37 pounds per mile. Between Altoona and Pittsburgh, with a maximum gradient of 52 feet per mile traveling east, and 95 feet per mile going west, at a speed of 33 miles per hour, these engines convey trains averaging 276 tons, exclusive of engine; the average consumption of fuel being 46 pounds per mile."

The Philadelphia & Reading Railroad Company exhibited a locomotive made by their apprentices. It was a freight-engine, 6 driving-wheels, 4 feet 6 inches diameter, with a 2-wheeled bogie in front. The fuel is anthracite. The fire-box, of steel, is 8 feet long by 42 inches wide, and 38 inches deep to crown; the tubes of wrought-iron, lap-welded. It was stated that the life of such a fire-box with anthracite coal was 175,000 miles.

The second of the tables shows the dimensions of Messrs. Porter & Bell's, and the Dickson Manufacturing Company's engines, for the 3-feet gauge. Of this class, there was also exhibited one not in the tables by the Baldwin Locomotive Works, which was running in the Centennial grounds, conveying passengers from one part of the ground to the other. There were two other engines also running on this railroad; one exhibited by the Mason Machine Works, of Taunton, Massachusetts, the other engine exhibited by the Brooks Locomotive Works, of Dunkirk, New York.

One important feature of the American locomotive appears to be the system of supporting the front part of the engine at a point as far forward as possible, *e.g.*, under the centre of the smoke-box, and throwing the supporting wheels well forward in advance of the front. The ordinary bogie, or 4-wheel truck, requires this, but the freight-engine, and some recent forms of passenger-engine, dispense with the 4-wheeled bogie-truck, the front part of the locomotive being carried on a pair of wheels, which are termed a pony-truck. These wheels are placed as much in front of the body of the engine as the leading wheels of the bogie-truck would be placed, and have a radial motion from the centre of the smoke-box. The use of the bogie, or of the pony-truck, to support the front part of the engine, insures as short a rigid wheel-base as possible. The passenger-engines have invariably four coupled wheels, as driving-wheels. The plan of limiting the rigid wheel-base to the driving-wheels, and of placing the front supporting wheels of the engine well in advance, gives very great steadiness of motion to the engines. A special train I traveled in on the Pittsburgh, Fort Wayne, & Chicago Railway, ran 50 miles in 51 minutes, including a stoppage at a level crossing of a railway, on a practically level grade; the engine and train were remarkably steady.

There are many points of detail about the engines which deserve notice. For instance, the fire-boxes are of steel; the tubes of iron (generally charcoal iron); the boiler is generally of steel.

Anthracite coal is used largely in the State of Pennsylvania, near the anthracite coal-fields. The table shows the relative size of fire-boxes for each sort of locomotive.

The injector is in use on almost all engines, but the confidence in it has not prevented pumps from being generally retained in addition.

A peculiar feature of the American locomotive is the head-light. These seem to have originated with the necessity for showing a strong light from the engine on approaching level crossings, which were formerly entirely unfenced; or in passing along the streets of towns where the railroad runs along the streets, much as tramways do in

England. The head-light is a lamp about 20 to 24 inches square or in diameter. The light is placed in the centre of a highly-polished parabolic reflector, and the oil used is of the best description; indeed, shops advertising the best oil for domestic use advertise it as head-light oil. In connection with these exhibits of locomotive-engines, it is interesting to make some mention of the working arrangements on one of the portions of the Pennsylvania Railway which I had the opportunity of observing. The principle of competition for securing economy of working is put in force as far as possible. The manager of the company informed me that they find it preferable to keep the several portions of the line distinct in regard to workshops, both for manufacture and repairs, and limited in respect to size to what one superintendent can so look after as to know what work every man is doing; the idea being that thus a comparison can be instituted between the cost and quality of the work at the several shops. Similarly with the working of the engines. A strict comparison of the cost of running is kept, and published among the men, and a system of premiums is also adopted. The engineer (which is what we term engine-driver) on American railways is a person generally of superior education to those on our railways. The engine itself is fitted up with great comfort in regard to seats and protection from the weather. There are guilds or associations, to which they belong. A system of premiums is, of course, subject to the difficulty that the engineer may occasionally supplement his supply of coal from the cars. But I was informed that this was not found to be at all a practical inconvenience, as the number of premiums is sufficient to induce each to watch the others closely in that respect; and only one case of such an occurrence was known. There are monthly premiums of \$20 (£4) to the engineer, and \$10 (£2) to the fireman; and second premiums of \$15 (£3) to the engineer, and \$7.50 (£1 10s.) to the fireman; and annual premiums of \$100 (£20) to the engineer, and \$50 (£10) to the fireman; and second premiums of \$75 (£15) to the engineer, and \$37.50 (£7 10s.) to the fireman. The premium on passenger-engines is based on the lowest cost per car hauled one mile; and for freight-engines, the lowest cost per loaded car hauled one mile. The results for premiums are taken from the monthly and annual printed reports of the performances of engines. A mileage of 1500 miles must be made in the month to entitle to monthly premium, and 18,000 miles in the year to entitle to annual premium. In calculating the mileage of freight-cars, five empty cars are counted as three loaded cars.

The exhibit by the Empire Transportation Company of the Ameri-

can fast-freight system closes the list of exhibits to which I propose to draw attention.

The United States railways have no system for the interchange of traffic, such as has grown up under the Railway Clearing House. The evils which arose from this were enormous. Each road, if but 50 miles long, had its own traffic, its own classification of property, its own time-tables, and charged its own rates, without regard to through contracts made by other roads. No efforts were made to forward through goods with speed. Bankruptcy of roads was not unfrequent; a solvent company, forming the link in the through route, would detain the goods for prepayment from its insolvent neighbor of accumulated freight charges. Such delays led to great damage to property; but if goods were damaged or delayed on the road, the delivering company would refer the owner to seek his remedy as best he could from the intermediate roads. In Great Britain these difficulties were never experienced in an aggravated form, owing to the earlier railways having allowed the through merchandise to be carried by Pickford, Chaplin, and Horne, and other great carriers already possessed of the carrying trade of the country. To meet the public wants of the United States in this respect several transportation companies have been formed, and the exhibit of the Empire Transportation Company was intended to exemplify this system, which has an extension beyond the railway systems. The Empire Company commenced its operations in 1865; its object was to increase convenience, promptness, and safety in the transfer of property between inland points west of the Philadelphia & Erie Railway and points on the Atlantic slope and seaboard, and with foreign countries eastward. The route consisted at that time of ten independent railways, whose discordant interests prevented unity of action. The Empire Transportation Company, formed of persons of railway experience and connections, became agents of these several companies. It became responsible to the parties forwarding goods for rates and prompt delivery.

It should here be observed that various other methods have been made to meet the difficulties above described. One was for the railway companies to co-operate with each other under a specific name, such as the "Purple Line," "Orange Line," "Planet Line." A board of management was formed, consisting of representatives from each interested railway. Each road furnished its own share of cars, which were painted a uniform color, and bills of lading and forms are all printed in the same color. This corporation contracted for the through delivery, if paid. The merit claimed for this system

as against the Empire Transportation Company's system is, that the sole cost to the railway is the actual expense of its operations; whereas some allowance must be made to the private corporation for its expenses and profit out of the rates charged. Against this the Empire Company allege that larger net earnings to the railway company result from the action of the private corporations in endeavoring to secure traffic; but in any case, the conflicting interests of the railways over which the company works would have prevented co-operation.

The Empire Company furnishes all the cars required for its traffic. It possesses pipe-lines for bringing the oil down from the oil regions to the road or river. It has its own stations for goods in New York, with its ferry-boats to cross the river, and a special oil depot at Communipaw for petroleum traffic. In New York harbor, warehouses are provided for the storage of petroleum in packages, and iron tanks for the petroleum in bulk, with facilities for the direct discharge into vessels alongside the shipping pier of petroleum destined for shipment. It has also a station at Baltimore. It has a subsidiary agency for the traffic on the lakes, for the carrying on of which it possesses from sixteen to twenty steam-propeller boats, and wharves and elevators for grain at Erie. The company exhibited its cars; its petroleum-oil transportation, both by car- and pipe-lines; and models of its shipping piers, its elevators, and steam-propellers.

CARS.—These are of the standard pattern. A large number have been specially fitted for traffic in fresh provisions and perishable articles. They are double throughout, lined, with a non-conductor of heat, and fitted with ventilators at the top and ice-boxes.

The tank-car for petroleum consists of a wrought-iron boiler on trucks, the boiler having a capacity of 3600 gallons. The boiler is fitted with a man-hole, expansive double valve, etc., and needs the best material and workmanship to secure its contents from leakage.

The following is the mode of collecting the oil by means of the pipe-lines and loading it into the cars. The pipe in use is of wrought-iron, lap-welded, usually two inches in diameter, put together with a screw-sleeve joint. The main pumping-line or lines are run from the centre of production by the most direct route to the railroad station. The pipe is laid along the surface of the ground, except at road-crossings, or where protection is necessary. At the railroad, large iron receiving-tanks are erected, varying from 5000 to 20,000 barrels capacity each. These tanks are placed at a sufficient elevation above the railway to permit their contents to be run by gravity through pipes to the loading-racks, where the cars stand in sidings about the

railway. At the necessary intervals along the pipe-line pumping-stations are established for the reception and forwarding of the oil. The station consists of a pump-house, with two or three powerful pumps, worked by steam; two tanks, of from 500 to 2000 barrels capacity each, in a substantial tank-house; a telegraph-office, and a building to accommodate the employee in charge. From each such station branch annexing lines lead off in every direction to the hundreds of wells that are tributary to it. At each well accurately-gauged storage-tanks are fixed, to which the pipe-line branches are attached. Before commencing to draw oil from these tanks their contents are measured and recorded; another means of record is made after the pipe-line ceases taking oil from them, and the difference in inches between the two measures forms a basis of credit to the well-owner in the company's works. A memorandum receipt, known as a gauger's ticket, is given to the well-owner at the time the oil is run into the pipe-line, and a negotiable certificate for all or any part of the oil credited to the well-owner on the company's books is issued on call at the pipe company's central office on a telegraphic request. All petroleum received goes into a common store, from which deliveries are made in accordance with orders received from the owners. The average capacity per 24 hours of a single main of two-inch pipe may be considered as about 40,000 gallons. From 1866 to March 31, 1876, the oil passed through the Empire Transit Company's pipes amounted to 375,810,551 gallons of crude petroleum. The quantity of petroleum held in store in tanks located in the Pennsylvania oil region may be stated as averaging from 80,000,000 to 120,000,000 gallons. In case of the conflagration of an oil-tank the loss is shared by the owners, in the ratios of the relative quantities of oil held for them at the time. From Karns City to the Allegheny Valley Railway the charge made for the use of the pipe-line was thirty cents per barrel, an allowance of a little over two per cent. being made for leakage and waste.

ELEVATORS FOR GRAIN.—The following is the description of one of the company's elevators at Erie: the structure is framed, 96 feet long by 72 feet wide, inclosed by a brick fire-wall, and has a slate roof. The main building is 109 feet and the tower 124 feet high. Forty-seven separate bins furnish an aggregate storage capacity of 250,000 bushels, and the transfer capacity direct from lake to rail may be estimated at 100,000 bushels per each twenty-four hours. A steam-engine furnishes the power requisite to do the work of the building. The plan of operating the elevator is as follows: A movable ship-leg, containing an endless rubber belt, 157 feet long

and 17 inches wide, on which 154 metal buckets, of nine quarts capacity each, are secured, is lowered from the house into the hold of an adjacent grain-loaded vessel. The belt is then started, and elevates the grain to the hopper of a 100-bushel receiving-scale, located in the elevator-tower, where it is weighed; after weighing the grain is dropped by gravity into an iron receiver, located below the floor of the building. From this receiver it is elevated on another similar bucket-belt to a large distributing bin at the top of the house. From this bin the grain is spouted by gravity into any one of the numbered storage-bins, from which it is again spouted (direct into cars) when ready-for shipment by rail. Two railroad tracks, accommodating six cars at a time, are located in the building below the storage-bins. On each railroad track there is a track-scale of the most approved pattern, which is frequently tested by sealed weights and kept in perfect repair. The light weight of each car is taken on entering the building, and the loaded weight as it passes out, the difference giving the weight of the grain. Each lot of grain is kept entirely separate and distinct from every other, no mixing or grading of grain being allowed. A small sample is taken from each lot of grain handled, and is preserved for reference if desired. Great attention has been paid to making the most perfect provision against fire losses.

It will be seen that the organization of the Empire Transportation Company is on a larger scale than that of any carrying company in Great Britain. Its functions are the result of the spread of the American railway system, the features of which are very different from our system. With us the railway companies have discouraged the private carrying companies from using the railways, and have preferred to take the whole carrying trade and profit into their own hands. Whether the American railway companies will do that eventually or not, it would seem, for the immediate future, that it would be worth considering whether this organization could not be utilized for the purpose of regulating the ruinous competition which has prevailed between the principal East and West routes terminating in New York and Philadelphia. If these companies would refer to arbitration the share which each should have of the through East and West traffic, and then place the agency for this trade and division of receipts in the hands of a large company, like the Empire Company, it might prevent the present difficulty.

It will have been seen, from the tabular statement of the locomotives exhibited, that several were for railways of the narrow, or three-feet gauge in America. It will, therefore, be desirable to explain the position which these railways have assumed in the United States.

Within the last few years a considerable development has taken place of railways on a three-feet gauge in America. It seems curious that we have no sooner ended the controversy between the broad and narrow gauge in England, by the adoption of the 4 feet 8 inches standard, than a new controversy has sprung up between the advocates of that gauge and a smaller one. This controversy has points of interest for us in connection with the question now of daily occurrence, as to how to connect small centres of population with our railway system at a moderate cost; and it has further points of interest in connection with our colonial possessions and India; for if it can be shown to be advantageous in America, it would be also advantageous in colonies where the circumstances are similar. As I have already observed, in England the railway is required to accommodate an established population, but in the colonies, as in the United States, the railway is at first simply the road of the pioneer. The business of the railway there is to develop the country, by enabling a population to enter it. Such a road must be constructed as cheaply as possible. In fact, cheapness is the first consideration. After the road has been made, a population developed, and revenue obtained, progressive improvements must take place in the line. The railways which have developed the United States have practically had to be reconstructed from their original form as population and traffic have increased. With these preliminary remarks I will proceed to describe the narrow-gauge, or three-feet railways, of the United States at the present time.

There are companies formed to build about 7973 miles of these narrow-gauge lines. Of these there are about 2700 miles at present in operation. The Denver & Rio Grande is proposed to be about 1700 miles long, and of these 210 miles are completed. It is difficult to give a general summary of the cost of the line, because the capital expended in almost all cases includes works on the portions of line which are still in progress. The estimate of the probable cost which the promoters of the narrow-gauge system give is as follows: About £1900 per mile of line with a 30-pound rail, and about £758 per mile for rolling-stock. The lines the particulars of which I have been able to obtain are the Montrose Railway and the Parker & Karns City Railroad. These lines are of different character. The Montrose Railroad is 28 miles long, and cost a little over £2300 per mile, including equipment of two locomotives, two passenger-cars and baggage-cars, and thirteen freight-wagons. This line is situated in an agricultural country. It runs from the Tunkhannock station of the Lehigh Valley Railway to Montrose, which is 28 miles distant, and

at a considerable elevation. The line follows closely the contour of the country, and works round the heads of ravines in a very striking manner; it has necessarily one or two viaducts. The traffic is mainly agricultural.

The Parker & Karns City Railroad is 10 miles long, and is to be extended immediately for a further distance of 17 miles. It cost £5500 per mile, including equipment of four locomotives, five passenger-cars, and forty-six freight-cars. The line has a viaduct, 400 feet long and 74 feet high. It follows very closely the contour of the country. This line is mainly for the development of a region of oil-wells opened somewhat recently. The goods traffic is mainly upwards, to supply the wants of the new settlers. The oil is carried in pipes to main stations of the Allegheny Valley Railway, which is near.

The curves on these lines are in places of 120 feet radius, and the gradients occasionally as steep as 1 in 40. The following is a comparison of the particulars of the rolling-stock for the 3 feet and 4 feet 8½ inch gauges:

PASSENGER ENGINE FOR 3 FEET GAUGE.

	4 wheels, coupled.		Average for 4 ft. 8½ in. gauge.
	For 30 lb. rail.	For 40 lb. rail.	
Diameter of cylinder . . .	8 in.	10 in.	17 in.
Length of stroke . . .	16 in.	26 in.	24 in.
Rigid wheel-base . . .	6 ft. 6 in.	6 ft.	8 ft. 6 in.
Total wheel-base . . .	$\begin{cases} 12 \text{ ft. } 0 \text{ in.} \\ 3 \text{ ft. or } 3 \text{ ft. } 4 \text{ in.} \end{cases}$	$\begin{cases} 15 \text{ ft. } 10 \text{ in.} \\ 3 \text{ ft. } 8 \text{ in.} \end{cases}$	$\begin{cases} 22 \text{ ft. } 5 \text{ in.} \\ 5 \text{ ft. } 2 \text{ in.} \end{cases}$
Weight on driver . . .	20,000 lbs.	24,000 lbs.	45,800 lbs.
Weight on pony-truck . . .	4,000 lbs.	8,500 lbs.	25,500 lbs.
Total, . . .	$\begin{cases} 24,000 \text{ lbs.,} \\ \text{or } 10 \text{ tons } 1 \text{ cwt.} \end{cases}$	32,500 lbs.	71,300 lbs.
Weight per wheel, on drivers	$\begin{cases} 5,000 \text{ lbs.,} \\ \text{or } 2 \text{ tons, } 4\frac{1}{2} \text{ cwt.} \end{cases}$	$\begin{cases} 6,000 \text{ lbs.,} \\ \text{or } 2 \text{ tons } 8 \text{ cwt.} \end{cases}$	$\begin{cases} 112,000 \text{ lbs.,} \\ \text{or } 5 \text{ tons.} \end{cases}$

	6 wheels, coupled.		
	Freight engine, Rails, 25 lbs.	Mogul pattern, 40 lbs. rail.	Mogul pattern, 6 wheels, coupled. 8 wheels, coupled.
Cylinder	9½ in. to 14 in. stroke.	12 in. X 16 stroke.	18 in. X 24 in. or 20 in. X 24 in.
Diam. of driving-wheels . . .	2 ft. 9 in.	3 ft. to 3 ft. 10 in.	4 ft. 6 in. 4 ft. 2 in.
Rigid wheel-base . . .	7 ft. 3 in.	9 ft.	15 ft. 13 ft. 8 in.
Weight, all on wheels . . .	20,000 lbs.	$\begin{cases} \text{Driver, } 34,000 \text{ lbs.} \\ \text{Truck, } 4,000 \text{ lbs.} \end{cases}$	$\begin{cases} \text{Driver, } 68,000 \text{ lbs.} \\ \text{Truck, } 12,000 \text{ lbs.} \end{cases}$
		Total, 38,000 lbs.	Total, 80,000 lbs. 91,640 lbs.
Weight per wheel . . .	$\begin{cases} 3,333 \text{ lbs.,} \\ \text{or } 1 \text{ ton } 2 \text{ cwt.} \end{cases}$	$\begin{cases} 5,666 \text{ lbs.,} \\ \text{or } 2 \text{ tons } 1 \text{ cwt.} \end{cases}$	$\begin{cases} 11,333 \text{ lbs.,} \\ \text{or } 5 \text{ tons } 1\frac{1}{4} \text{ cwt.} \end{cases}$ 9,925 lbs., or 4 tons 1 cwt.
Hauling capacity {	On level . . . 468 tons	795 tons.	
	On incline of $\frac{1}{100}$. 145 tons.	250 tons.	
	On incline of $\frac{1}{50}$. 63 tons.	109 tons.	

The consolidation pattern engine hauls over line with gradients of 1 in 69 a gross weight of 476 tons.

It will be seen from this that the principle adopted in these narrow-

gauge engines is to keep the centre of gravity low, and to diminish the weight on each driving-wheel to a little over 2 tons. The rigid wheel-base is diminished so as to facilitate passing around curves.

In the cars for the narrow gauge the wheels are made 24 inches in diameter instead of 36 inches, which is the usual diameter for passenger-cars. The usual system of a long body placed on swinging trucks is in use. The original cars were 35 feet long. The weight of the cars is from 15,000 to 17,000 pounds, carrying 36 passengers, or say from 410 to 470 pounds in dead weight per passenger. In those that I saw, the sizes and scantlings were all reduced in proportion to the gauge. The 4 feet 8½ inch car carries from 50 to 70 passengers, and weighs from 28,000 to 33,000 pounds,—*i.e.*, from 500 to 600 pounds dead weight per passenger. The car is 7 feet wide. The width of 7 feet allows double seats on one side 36 inches wide, and single seats on the other 19 inches wide, with an aisle between 17 inches wide. In order to balance the carriage the arrangement is reversed in the middle of the car. The width of 7 feet was fixed upon the principle of making the width of the car little over double the width of the road, but the width has since been increased to 8 feet in order to seat 6 passengers abreast; the number of passengers is thus increased to 47 without a proportionate increase of weight. The height of the centre of the draw-bar and buffers is 24 inches above the rail.

The freight-cars are 23½ feet long and 7 feet wide; the wheels are 20 inches diameter, but recently wheels of 24 inches diameter have been introduced.

The following shows a comparison between the weights and carrying capacity of some of the cars :

Gauge.		Weight of Car in Pounds.	Capacity in Pounds.	Total Weight.	Proportion of Dead Weight to Paying Loads.
FLAT CAR.					
4 feet 8½ inches	. .	16,000	20,000	36,000	1 to 1.25
3 feet . .	. .	7,500	19,000	26,500	1 to 2.5
BOX CAR.					
4 feet 8 inches .	. .	17,000	20,000	37,000	1 to 1.17
3 feet . .	. .	10,000	17,600	27,600	1 to 1.6
COAL CAR.					
4 feet 8½ inches	. .	17,000	30,000	47,000	1 to 1.7
3 feet . .	. .	9,000	20,000	29,000	1 to 2.2

On the Denver & Rio Grande Railroad it is stated that 16 cars on the 4 feet 8½ inch gauge unload and fill 20 cars on the 3 feet gauge. Thus, say,—

Empty Weight.	Paying Loads.	Total Dead Weight.	Total Paying Load.	Total Cars and Load.
	Tons.	Tons.		
16 wide gauge, 8½ tons . .	10	136	160	296
20 narrow gauge, 5 tons . .	8	100	160	260
Saving in total weight				36 tons.

Which is equivalent to 22 tons additional freight, or 23 per cent. more, assuming the cars loaded to the full capacity, and the comparison is more favorable when the cars are not filled. It will be seen from these figures that the narrow or 3-foot gauge cars, as at present constructed, carry a larger proportion of paying load to dead weight than the cars of the standard or 4 feet 8½ inch gauge.

But these railways have only been in operation for a limited time. The stock on the 4 feet 8½ inch gauge has materially increased in weight since the commencement of the railway system. Indeed, the weights have increased one-half, and in some cases doubled, since I was in America in 1856. This increase has been caused simply by the necessity of adopting a degree of strength sufficient to resist shocks received in the course of traffic. The narrow-gauge cars have been constructed hitherto on the principle of reducing the dimension of the rolling-stock in proportion to the reduction of gauge. But inasmuch as the promoters of the narrow-gauge claim that they can carry the weights in the cars which I have shown, and as they state that speed of from 15 to 20 miles an hour will be maintained, it is clear that an increase of weight may be expected, except so far as a saving may arise from the diminished size of wheels.

The narrow-gauge lines which I have inspected followed with great ease the contour line of the ground, and if the cars are kept narrow, the width required for the formation of the lines would be narrower. But the width of the cars is being gradually approximated to that of the 4 feet 8½ inch gauge, consequently that source of economy must disappear. The width of cars of 8 feet with a base of 3 feet is, moreover, unstable, but whatever proportion between the width of gauge and width of car be safe on the 3-foot gauge will be equally available for adoption on the 4 feet 8½ inch gauge, and therefore this is not an element of comparison between the gauges.

I may mention in connection with this that the facility of passing around curves is much increased on the United States railways by the short amount of rigid wheel-base as compared with that of English carriages and wagons.

The use of radial axles, however, diminishes the difficulties of a long, rigid wheel-base; moreover, in America, experiments have been

made which tend to show that axles may be introduced on which the wheels have a power of motion independent of each other. A train with such wheels and axles was running on the narrow-gauge railway at the Centennial Exhibition, and a pair of wheels with this axle was exhibited which had been in use for several months, and had run 12,000 miles in ordinary trains. This is called the Miltimore axle. Consequently, in practice, it may be assumed that the 4 feet 8½ inch gauge could be laid with curves little less sharp than those of the 3-feet gauge.

The weight of the rail depends entirely on the weight on any one of the wheels of a train. The light locomotives on the narrow gauge do not require heavy rails, but the measure of the power of a locomotive to draw a train up an incline is practically the weight upon its driving-wheels. The light locomotives can only draw light weights up the inclines in use on mountain narrow-gauge lines.

There is one advantage of the 3-feet gauge in the United States for lines of small traffic, which would not be so apparent in England,—viz., the convenience of having smaller cars to move about at the stations. The very long carriages in ordinary use on American railways are somewhat cumbrous for places of smaller traffic.

The break of gauge entails the cost of transshipment at junctions. The inquiries I made show that the cost of transshipment in the United States may be assumed at from 10*d.* (20 cts.) a ton, in cases of regular traffic, to 1*s.* 6*d.* (37½ cts.) a ton, in cases where traffic is slack or intermittent.

These railways have been constructed in the United States as economical pioneer lines. So long as they are retained in that capacity, they may be useful for opening out a country where the traffic is small; but they must be kept in their proper place, and they must not, as they seem to be somewhat inclined to do (as in the fable of the frog and the bull), attempt to swell out their rolling-stock to do what the 4 feet 8½ inch gauge can do. It is quite certain that in districts where the traffic increases and becomes of real importance, it will be necessary that these narrow-gauge lines be reconstructed and converted into lines of the 4 feet 8½ inch gauge, and in such cases the narrow-gauge stock will become somewhat of an incubus.

The tariff on the railways of the United States varies very considerably. From 2 to 3 cents, or 1*d.* to 1½*d.*, per mile is a frequent tariff, but with competing lines of course a very different tariff prevails.

The only division of classes which prevailed on American railways when I was there twenty years ago was the emigrant class, which was

carried at a very much lower rate than the other class; but it was then the custom to reserve cars for ladies, and for gentlemen who accompanied them. Now, the railroad corporations have created a first class, far more comfortable and luxurious than the first class on English railways, by the adoption of the saloon-car, or the Pullman car, for the use of which a special charge is made by the owners of the car apart from the fare. On railways which have not made terms with the Pullman Palace Car Company, cars equally comfortable are run on certain through trains, which are nominally owned by the officers of the company, so as to evade the State law, which does not recognize a differential fare.

I do not propose to enter here into the general question of charges for freight. It is, however, of interest to allude to a few points connected with goods and mineral traffic:

1. The question of coal.
2. Grain traffic to the East.
3. The laws passed in the Western States for enabling local traffic to participate in the benefits of low rates charged in competitive through traffic.

1. The coal question assumed considerable prominence in Massachusetts, from the fact that certain towns, which were essentially manufacturing towns, of which Lowell is a type, had depended for their progress on water-power. When the growth of the towns had exhausted this power, the use of steam became essential to their further progress. The price of coal for inland towns was regulated by the charges for transport, but seaboard towns obtained coal from Pennsylvania by sea. Lowell was 26 miles from tide-water. Fall River was on the southern seaboard. In 1865 Lowell had 385,412 spindles, and Fall River 241,218. Seven years later the spindles in Fall River had increased to 1,017,144, while those in Lowell had only increased to 570,586.

The want of a cheap tariff for coal in Massachusetts results from the great increase of its manufacturing industries. This increase is very forcibly illustrated by the fact that while the development of industry in the States between 1848 and 1865 had risen from \$125,000,000 to \$520,000,000, to that increase the original industries of the State—viz., agriculture and fisheries—had contributed $\frac{1}{80}$ per cent. only, foreign commerce had contributed $3\frac{1}{2}$ per cent., but the manufacturing production had undergone the amazing development of \$326,000,000, or 77 per cent. of the whole.

Various proposals have been made for the cheap conveyance of coal to the New England States, among others, that of narrow-gauge

coal-lines from Pennsylvania. It is unnecessary to point out that if any line were made for the special conveyance of coal it should be at least on the 4 feet 8½ inch gauge.

With the exception of the New England States, coal extends largely under most of the Northeastern States of the Union. In Pennsylvania it is largely worked.

Of the railroad corporations in that State, there are some that owe their existence to having been previously owners of coal-fields, such as the Delaware & Hudson Canal & Coal Company, the Delaware, Lackawanna, & Western Railroad, and the Pennsylvania Coal Company; while the Lehigh Valley Railroad, the Philadelphia & Reading Railroad, the Central Railroad of New Jersey, and the Pennsylvania Railroad have become possessed of coal lands. The Philadelphia & Reading has indeed so fettered itself by the acquisition of coal lands that, owing to the present stagnation of trade, it has been temporarily obliged to suspend dividends on ordinary capital. With a revival of trade a great future is before it.

These railroad corporations, being so largely interested in the coal trade, entered into an arrangement termed the Coal Combination, by which they regulated the prices and the output of all the collieries on their lines, owners of private collieries being compelled to accede to it by the monopoly of transport in the hands of the companies. Such an arrangement shows to what lengths railroad corporations, possessing a complete monopoly, might carry their control over produce and manufactures. In this case an agreement between six corporations ruled the price of a commodity of the highest importance for manufacturing and domestic purposes. The stress upon the arrangement came when, owing to incidents of trade, the amount carried by one of the corporations was larger than what the united companies had decreed as its share; and, on the refusal of that corporation to reduce the quantities carried, the association broke up.

2. The grain traffic from the West to the East lies over five routes, —the Baltimore & Ohio, *viâ* Newark and Sandusky; the Pennsylvania, *viâ* Fort Wayne; the Erie and its connections; the New York Central and Lake Shore; the Grand Trunk and Michigan Central, of Canada. Moreover, the Lehigh Valley Railroad possesses a route on the Erie Road to the lakes; and the Erie Canal affords another route, *viâ* the Hudson River.

These railroads have been carrying the grain for through traffic, during the summer, at ruinously low rates in competition. The system is to retain the grain in the West. When ordered for Europe, it is put in cars and brought straight to New York or Philadelphia for ship-

ment, and thus there is no warehousing until the grain reaches Liverpool. It is calculated that grain can reach Liverpool in 18 days from the West; of course the low rates charged during the summer have answered well for farmers and shippers of grain, but unless remunerative for the railroads these low charges cannot be maintained.

I was informed by the Pennsylvania Railroad Company that the cost of haulage per ton per mile, including all expense of haulage, in 1875, was 3 mills ($\frac{1}{4}d.$) per ton per mile; therefore, at this rate, the actual haulage would be covered by a charge of \$2.25 from Chicago to Philadelphia. There appears, however, to be a strong conviction that the Western farmer cannot sell his grain in good years at such a price as will pay a fair rate for carriage to the railroad company as well as to enable him to obtain a footing in European markets with a reasonable profit to himself. He finds it better to feed and sell the resulting meat. If this be so, it would seem that the best prospect for the Western farmer is to look for a market in the establishment of manufactures and the development of the coal-fields of Illinois, near the seat of his produce.

LEGISLATION IN THE WESTERN STATES.—The problem of railway legislation in the United States differs from that in this country. In Great Britain the whole mileage of railways is about 16,400 miles. The legislation upon railway matters is regulated by the Imperial Parliament, and is, consequently, uniform over the whole country. In the United States there are now about 74,000 miles of railway in operation, and each State is self-contained as regards its legislation. The railroad may, however, pass through the several States or Territories. Railroads of which the whole line is within the confines of one State, are subject to the laws of that State only; but the railroad corporations whose lines lie in more than one State, become subject to the laws of these several States. In this matter of railway legislation each State has commenced from its own stand-point, consequently there has been no uniformity in the original legislative action of the several States; moreover, rapid alterations have occurred in the legislative proceedings taken by each State with respect to railroads. The Federal Government legislates upon railroads in the Territories, but when the Territory expands into a State, the State Legislature takes up the legislation.

The chairman of a leading English railway has said that so long as Parliament is sitting no railway property is safe in this country; this saying is, however, far more applicable to railroad property in the United States, owing to this diversity of legislative action in the several States, and owing to many of the State Legislatures being in the

hands of a class who do not always possess practical knowledge of the commercial wants of the community, but seem to be ready to make experiments without considering the resulting effects which the experiments may have in the confidence of the moneyed classes. If space permitted, it would be interesting to trace the alterations in the railroad legislation in the several States, and the effect on railroad property. I must limit myself here to alluding to the legislation which took place a short time ago in some of the Western States with the object of preventing the railroad corporations from charging differential rates. The history of this legislation deserves careful study by those in this country who would fetter the discretion of railway companies in charging what rates they please within the maximum rate authorized by Parliament.

In consequence of the severe competition between certain railroads in the Western States and also railroads running thence to the Eastern seaboard, very low rates were charged between competing points, whereas higher rates were maintained for shorter distances where there was no competition. This is a practice which has been recognized as admissible by the Court of Common Pleas in this country and the Railway and Canal Traffic Act. In 1871 and 1872 the States of Illinois, Iowa, Minnesota, etc., passed general acts, in which it was enacted that no railroad corporation organized or doing business in the State should charge for the transportation of goods or property on its road for any distance the same nor any larger amount as toll or compensation than is at the same time charged for the transportation of similar quantities of the same class of goods over a greater distance of the same road.

In 1873 the State of Illinois altered this enactment, to the extent that they published in a new act a tariff of rates and a classification of articles; but the act allowed the railroad corporation to fix their own rates and charges. Where, however, there is a conflict of opinion as to the reasonableness of their rates and charges, the law makes the schedule of the commission, not absolute, but *primâ facie* evidence of reasonable rate of charge. The law also makes the charging more for transportation to an intervening or non-competing place than is charged for transportation to a greater distance, *primâ facie* evidence of unjust discrimination.

In Iowa, the act of 1874 publishes a schedule of rates and a classification of goods, which it fixes as absolute. It divides the railroads into three classes. Class A carry \$4000 a mile a year and over; Class B carry \$3000 a mile a year and over; Class C, earning less than \$3000. The passenger rates are fixed at 3 cents per mile per pas-

senger, with 100 pounds of luggage for Class A; $3\frac{1}{2}$ cents for Class B; 4 cents for Class C; children under 12 half-price. Ten cents extra allowed to be charged if tickets are not taken before starting. The maximum charge for goods is to be, for Class A railroads, 90 per cent. under, for Class B, 5 per cent. over, and for Class C, 20 per cent. over, the published schedule; the railroad corporation being allowed to charge what they choose within this maximum. I understand a similar law has been enacted in Minnesota.

It is worthy of note, that in the case of suits instituted in Illinois to enforce the laws, the Bench enunciated the opinion that a railroad being an artificial person, created by the Legislature, cannot have higher rights than an individual person; that no individual can have any rights except those conferred by the Constitution; that railways are public institutions, and receive their title and property only for the public use; that the property thus intrusted to railroad corporations is to be used by them as a part of the public domain, controllable by the Legislature; that the character of railroad corporations does not grow out of the fact of their incorporation, but out of the manner and object for which they are created; the right to control them by the law-making power of the State is not founded on their being incorporated, but on their being the instruments of government, created for its purposes. These views deserve the careful attention of intending investors in Western railroads.

CONCLUSION.—I have endeavored, in these remarks, to show the present condition of the railway system of the United States, as compared with what it was when I reported upon it to the Board of Trade in 1856.

The relation of the railway to the public involves problems more complex in America than in this country, because the territory is so vast, the corporations so numerous, the interests of the various districts are so diverse, and each State's Legislature has its own views of the question of railway legislation. Moreover, the necessities of the country have required a mode of original construction which entails a large subsequent outlay to perfect the system.

Under these circumstances the foreign capitalist, who may have invested in railroad bonds at a high rate of interest, imagining that his security was as safe as that of English railway debenture, may have been sometimes disappointed. There are, however, lines which are as sound financially as our own leading railways. It would be prudent in English investors to confine themselves to those, and leave it to persons on the spot to support newer and less-known railways.

CONTINUOUS RAILWAY BRAKES

The want of a good continuous brake was felt almost simultaneously with the invention of locomotives. Roberts took out the English patent No. 6258 on April 13, 1832. George Stephenson, the father of the railway, also appreciated this need, and took out the English patent No. 6484 October 7, 1833. Twenty years ago experiments were made on the New York & New Haven, Michigan Central, Old Colony, and other roads, and some thirty or forty American patents were granted for various devices. None were introduced to any extent up to the year 1870, excepting Creamer's spring-brake and Loughridge's chain-brake. The former, a device only intended for emergencies, was so arranged that the brakemen could wind up by hand a spring-coil on each car, the clips to which were attached to the bell-cord. When the engineer saw danger ahead he pulled the bell-cord from the locomotive, which released the springs and applied the brakes. The Loughridge brake was operated by a chain running the length of the train, connected between the cars by a simple hook, having a loop under each car. By pulling this chain the tendency to straighten the loop caused (by a simple arrangement of levers and pulleys) the brakes to act against the wheel with a force depending upon the power applied to the chain. This chain was drawn up by a windlass which was caused to revolve by pressing a friction-wheel, fastened upon it, against the flange of the driving-wheel. A device was used with the intention of causing the friction-wheel to slip when the brakes were fully applied. This friction-wheel frequently broke the chain, and, to overcome this difficulty, Loughridge used a long cylinder, the piston of which is attached to the end of the chain, and the chain is drawn up by ordinary steam-pressure from the boiler of the locomotive.

Much progress has been made within the past few years in the devices to secure a perfect control of trains by brakes. After a train of cars has been under motion, a momentum is stored up proportionate to headway made and speed of train. This momentum has to be destroyed almost instantly, and can only be destroyed with safety by the use of friction appliances, causing the whole weight of the train to slide, or partly slide, upon the rails. As the result is seriously affected by the loss of time, we have the necessity of instantaneous action forced upon us. To instantly utilize the weight of the train in destroying its momentum requires the transmission of a force from

one point to ten or twelve different bodies, which have a limited motion in every direction. The force distributed upon the wheels of an ordinary American car amounts to not less than twelve tons, or for a train of ten cars and an engine a force of not less than two hundred tons must be instantly distributed among the wheels of the train, according to the weight with which each wheel bears upon the rail. A further necessity is that this force must yield to every irregularity in the motion of the running gear.

The Westinghouse brake as now manufactured can hardly be considered the same device as when first brought out in 1869. In its original construction it consisted of two essential parts, a power-generating apparatus and a system for transmitting this power to all of the wheels of a train when wanted. The first part consisted of a direct-acting air-compressing pump attached to the engine, and driven by steam from the boiler, and a main reservoir also upon the engine. This pump maintained a steady pressure of about eighty pounds per square inch in the reservoir, as indicated by a gauge in the cab. The second part consisted of a brake-cylinder with piston arranged to press against the brake-levers, and a length of pipe with a branch leading to this cylinder. These pipes were united from car to car by flexible hose connections, furnished with couplings containing valves so arranged that when the couplings were united there would be an open communication from the engine back along the train to the coupling at the rear end, which was closed by its valve. On the engine was a three-way cock having one connection to the main reservoir, and one to the brake-pipe extending the length of the train. The engine-driver by simply turning the handle of this cock could admit air from the main reservoir to the brake-pipe, and thus cause all the pistons to be thrust forward, bringing the blocks against the wheels with any desired force. If the train broke in two, the couplings, being held together by springs, would separate without injury, and the valves would close and the brakes remain on. The brakes were released by again turning the handle of the three-way cock so as to allow the air in the cylinders and brake-pipe to escape, when strong springs pushed the pistons back.

This system partly met the requirements, as will be seen :

1st. The power was stored on the engine, ready for use where most needed, and was an elastic substance.

2d. Each car had the cylinder and connections so arranged that an equal pressure would do a like amount of work in all cases.

3d. The force, being an elastic one, insured an equal proportionate pressure against all of the wheels.

4th. The power was not affected by the oscillation of the cars, as the connections were flexible and were unaltered in capacity or length.

5th. Sufficient power was insured to cause the whole train to slide upon the rails if desired.

The principal points of weakness in this brake were as follows: The failure of a pipe rendered the brake temporarily useless. The breaking in two of the train rendered the brake inoperative on the rear portion. The time required for the air to flow back through the long tubes under the cars prevented the instantaneous application of the brake.

Experience demonstrated that several contingencies might arise: (1) The engineer might observe an obstruction on the track, a broken rail, etc. (2) The train attendants might discover a car on fire or off the rails. (3) The brake-power might fail. (4) The train might break in two. It was also found that the saving of even a second in the application of the brakes would in many instances prevent or greatly lessen damages. The contingencies made it necessary that the brakes could be instantly and fully applied by the driver, conductor, or any other employee, from any part of the train, and that the brakes should be automatically applied by a sudden failure of the brake-power, or by the breaking in two of the train.

The Westinghouse automatic brake, as now in use, it is claimed fully meets every requirement that can possibly arise, and is the result of a long series of careful experiments. The same air-compressing apparatus, main reservoir, three-way cock, brake-pipe, and cylinders are used with the automatic as with the first system. In addition, the tender and each car have a small reservoir and triple valve located near the brake-cylinder. The connection from the main brake-pipe is made to one opening of the triple valve, and from a second opening a pipe leads to the brake-cylinder, while a third opening connects with the auxiliary reservoir. The connections between the cars have malleable iron couplings without valves, and cocks are put in the pipe at each end of every vehicle; all of these cocks, except the one at the rear of the train, being kept open when the train is connected. When the brakes are off, a constant pressure of about eighty pounds per square inch is maintained in the main reservoir, brake-pipe, triple valves, and all auxiliary reservoirs throughout the train. The brakes are applied by causing a decrease of pressure in the brake-pipe, which shifts the triple valve on each car, so as to close the port to the brake-pipe and open a port, which permits air to flow from the auxiliary reservoir direct to the brake-

cylinder, when the piston actuates the brake-levers as in the first system. The engineer causes this decrease by simply turning the handle of the three-way cock in the cab so as to permit a portion of the air to escape from the pipe. A valve is placed in the pipe under each car connected to a cord running through the interior of the car, and any person in the train by pulling this cord can open the valve, allow the pressure to escape from the pipe, and thus apply the brakes to the whole train. If the train breaks in two the couplings part, and the air escapes from the pipes on both detached portions, applying the brakes to both instantly. The derailment of the train would cause their application in the same manner, as a train always breaks in two when a portion leaves the track. The bursting of a hose or pipe would also discharge the air and apply the brakes. To release the brakes the engineer turns the three-way cock, so as to allow the pressure in the main reservoir on the locomotive to flow back through the pipe, when the triple valves shift to their original position, opening a port from the brake-pipe to each auxiliary reservoir, and giving it a fresh supply of air, closing the connection between the auxiliary reservoir and brake-cylinder, and opening a port which allows the air in the brake-cylinder to escape and the piston to be pushed back by springs.

In this system the air is stored in the auxiliary reservoirs, close to the brake-cylinders, and no appreciable time is required for its passage into the cylinders, hence no time is lost by the air having to flow back through long tubes, the transmission of the power being effected when the brakes are not in use. A reduction of only fifteen pounds in the pressure in the brake-pipe is sufficient to shift the triple valves and apply the brakes, and this reduction can be made in less than one second. A slight reduction of pressure applies the brakes slightly, and they may be applied with any desired force up to the maximum.

The Henderson hydraulic brake, as its name implies, is worked by hydraulic pressure, and is very simple in its construction and application.

The Goodale steam-brake is worked somewhat like the air-brake, except that steam is used instead of air.

The Smith vacuum-brake is worked by means of an ejector on the engine, which exhausts the air from two collapsible rubber cylinders under each car, through pipes running the length of the train. The atmospheric pressure collapses these cylinders and actuates the brake-levers attached to one head of same. This arrangement is very simple.

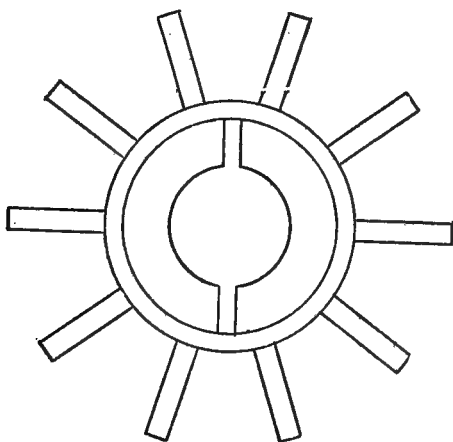
CHILLED CAST WHEELS FOR RAILWAYS.

BY FELICIAN SLATAPER.

According to Wood's *Practical Treatise on Railroads*, the first railways were laid in England between 1602 and 1649, the precise date being unknown. The first rails were of wood, on which were run wagons, having wheels of wood, for carrying coal from the mines to vessels. About 1738 cast-iron rails were first used, and about 1753 cast-iron wheels began to be substituted for those made of wood. The first cast-iron wheels were not chilled; they were cast in one piece, the hub being connected with the rim by straight spokes. The tread, not being hardened, soon wore out, and to remedy this the wheels were cast in a "chill,"—or, as it was then defined, "case-hardened."

The property which cast-iron possesses, of becoming hard or chilling when run in a molten state against cold iron, must have been known at a very early date to those engaged in the smelting of iron. Before chilled wheels were made chilled iron had been used in parts of plows, the face of forge-hammers, punches for punching holes in heated tires for wagon-wheels, and for other purposes. Wheels with cast-iron hubs and rims, and flat wrought-iron spokes cast into the hubs and rims, were used on the turnpike at Mauch Chunk, Pennsylvania, in conveying coal to the river, in 1826: whether they were chilled or not is not mentioned (see *Journal of the Franklin Institute*, vol. vi. page 360). Wheels of this form were used at this point, with chilled rims, on the completion of the railroad to the river. In vol. viii. pages 281 and 352, of the same journal, are extracts from Wood's *Treatise on Railroads*, which show that the wheels first used under locomotives and cars in England were made of common cast-iron; that they afterwards had wrought tires shrunk on them; that the durability was 5 to 1 in favor of the wrought-iron tire; and that prior to 1831 wheels with chilled treads were in general use in England. Mr. Wood thus describes "cast-iron wheels case-hardened": "A complete remedy was, however, effected a few years ago" (for cast-iron wheels, not chilled) "by what is called 'case-hardening' the rim of the wheels. This is done by placing a massive ring of cast-iron around the mould for forming the casting of the wheel, and running the metal which forms the exterior surface of the rim of the wheel against this cold, cylindrical piece of iron. The rapid abstrac-

tion of heat by the cold iron produces such a degree of compactness and hardness to the surface of the wheel in contact with the cold iron, that the file has no effect upon it, and this hardness effectually prevents the action of the rail from wearing the wheel into grooves." The great difficulty attending the making of chilled wheels was here encountered, which Mr. Wood thus describes: "The operation of case-hardening was at first attended with great difficulty; the rapidity with which the cold iron caused the rim to cool produced an unequal contraction of the metal, in all the several parts of the wheel, and made them frequently fly in pieces. The rim, being first cooled, would not yield to the contraction of the spokes in cooling; and therefore, when the spokes cooled, if the contraction did not cause them to separate immediately, it left such a tension upon them that the shock they received when brought into use soon made them crack, and thus rendered the wheel useless. The plan now mostly used, where the wheel is formed of cast-iron, is to cast the nave in



two pieces, two hoops of wrought-iron being laid around the nave to secure it. The universal adoption of case-hardened wheels on all the principal railways, in preference to the common wheels, is the best evidence of their superiority. It will be subsequently seen that the cast-iron wheels of the Killingsworth engine had been hooped with wrought tires."

It is not definitely known at what date the first cast chilled wheels were made, but in 1816 a patent was granted to Losh & Stevenson for a wheel with a solid cast-iron hub, connected by wrought-iron spokes to a cast-iron rim "case-hardened" on the tread.

The cast-iron wheels described, even with the hub divided into two sections, to partially relieve the spokes from the tension produced by the unequal contraction in cooling, were not strong, and did not prove very satisfactory in service. They were, therefore, soon supplanted by wheels with cast-iron centres and wrought-iron rims or tires, and such wheels were in quite general use in Great Britain when railways were commenced in this country, about 1830.

Probably the first chilled wheels used on a railroad in this country were made by Jonathan Bonney, at Savage Factory, Maryland. They were of the ordinary flat-spoke pattern, and were used on the Baltimore & Ohio Railroad; this fact is substantiated by Mr. William Belt, now a resident of Wilmington, Delaware, who worked for Mr. Bonney, in Maryland, in 1829, and removed with him to Wilmington in 1830. Wheels of this form were made by Jonathan Bonney & Co. in Wilmington, in 1833 or early in 1834; they were used on the railroads leading out of Philadelphia, and on the New Castle & Frenchtown Railroad. About the same time, wheels of the same form, but with a wrought-iron ring imbedded in the tread, were made by Mr. Ross Winans, at Baltimore, under a patent granted to Phineas Davis, whose claim was "the use of a ring or hoop of wrought-iron, to be laid and cast within the body of a railroad-wheel, in such manner as to operate as an internal chill, to cool more rapidly, and consequently to harden the part under the curve or cone near the flange." Spoke-wheels were generally made with 12 spokes when the diameter was 33 inches, the spokes at the hub about 2 inches less in width than the length of the hub, and at the tread nearly the width of the latter. To prevent the arms or spokes from breaking by the shrinking of the hub, which remained hot longer than the rim, it was necessary to separate the hub longitudinally in three places, as annealing or cooling in hot sand was not then practiced by iron-founders, except in a limited way. The openings or slots in the hub were filled with iron keys, or with some kind of metal, like type-metal, that would expand in cooling, and a strong, wrought-iron band was shrunk on each side of the hub. The wheel was then bored and pressed on the axle, the wrought-iron band receiving the strain produced by forcing the axle on to the hub, and of the key then used, to prevent the wheel from becoming loose on the axle. These chilled wheels were in general use here until the great increase of our railways, the substitution of the heavy T-rail for the light, flat bar-rail, and the greater weight and speed of our trains, made a stronger and more durable wheel necessary for economy and safety.

Many attempts were made to cast chilled wheels with a plate or

plates connecting the hub with the rim, instead of spokes, and the records of the United States Patent Office show that from 1830 to 1848 there were forty-six patents granted relating to railroad-wheels, most of which were for forms of patterns, or for some device for overcoming the strain or tension produced by the unequal contraction in cooling, as before described. Some good wheels were made of the plate patterns; but all, if well chilled, had more or less strain on the plate after cooling, which rendered them very liable to break in service, and most of them broke before they were worn out.

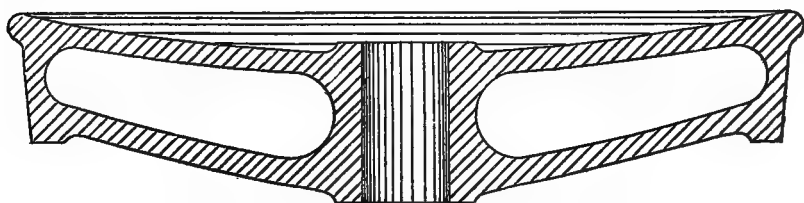
In 1833, John Elgar, of Baltimore, patented a wheel, with a chilled rim, cast-iron hub, and two wrought-iron plates, convex on the outside, either curved or conical, the plates riveted to the hub and rim. This was the first plate-wheel made. It was expensive, and did not supersede the spoke-wheel.

Many others obtained patents for wheels of different kinds, some with wooden spokes and felloes, cast-iron hubs, and wrought-iron tires; some of cast-iron with three wrought-iron hoops forming the tread, and others having cast centre, chilled flange, and wrought-iron tread, etc. The spoke-wheels with chilled treads were, however, used almost universally for truck-wheels for engines, tenders, and cars, up to 1838. Truck-wheels for engines were generally made with flanges on one or both sides of the arms or spokes, and on the inside of the tread between them. Spoke-wheels were also devised and patented, with the spokes of divers forms and arranged in various ways, none of which were any improvement on the ordinary spoke-wheel, excepting probably that of Henry R. Dunham, patented February 15, 1838, which was for a series of spokes, the hub being split longitudinally, to allow for contraction, and a hollow rim. This wheel possessed an advantage over the spoke-wheel,—a hollow tread,—but it was not used to any great extent, on account of the introduction of the double-plate wheel about the same time. Many spoke-wheels made of iron, possessing the proper degree of tenacity and chilling properties, qualities not generally combined, proved satisfactory. The absence of these properties in the iron used, and the want of skill on the part of the manufacturers, caused many to break, and to wear rapidly. Spoke-wheels, if not made of suitable iron, and selected with great care, are liable to break in the tread between the spokes, especially when not chilled deep,—and but few were chilled as deep as the plate-wheels now are; they would wear flat opposite to the spokes.

The desire to remedy these inherent defects in the spoke-wheel led to the invention of the plate-wheel. All attempts in this direction,

however, prior to 1838, were unsuccessful, because proper provision was not made in the form of the wheel for the unequal contraction of the different parts, and they consequently broke or split in cooling. The practice of pitting, or gradual cooling, had not then been introduced among wheel-makers.

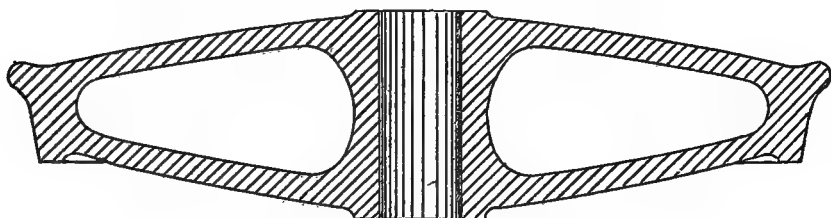
Early in 1838, wheels were made by Truscott, Wolf, & Dougherty; and a patent was granted to them on March 17 of that year for a



Truscott, Wolf, & Dougherty. March 17, 1838.

wheel cast in one piece with a solid hub, connected with the rim by two curved plates, running parallel to each other, or nearly so, the outside plate convex, and the inside plate concave. This wheel was not a success, and did not come into general use.

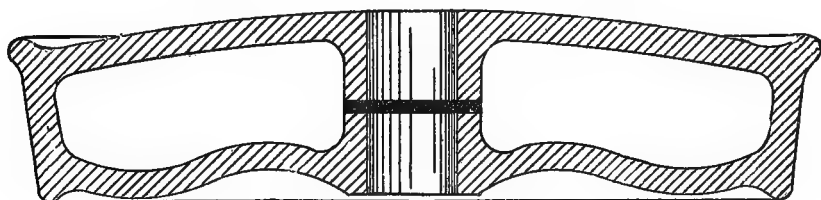
About the same time, George D. Lobdell devised and patented, on March 17, 1838, the double-convex plate-wheel, known among rail-



Bonny, Bush, & Lobdell. March 17, 1838.

road men as the Bush & Lobdell wheel, which was used for several years, almost exclusively, under engines, tenders, and passenger-cars, and also extensively under freight and other cars. This wheel was cast in one piece, the plates or disks were convex on the outside, the hub divided transversely, to prevent the cracking of the plates in cooling; the contraction of the rim, which took place first, had a tendency to open the plates, thus preventing them from being on a strain, and allowing them to yield when the hub cooled; the slot being filled with type-metal before being drawn on the axle. This form of wheel was very strong, admitted of a very perfect and uniform chill, and was free from the objection and defects of the spoke-wheel.

Many of them made very great mileage,—one that was on exhibition at the International Exhibition having been in use for twenty-five years on the New York & Erie Railroad, others on the Philadelphia,

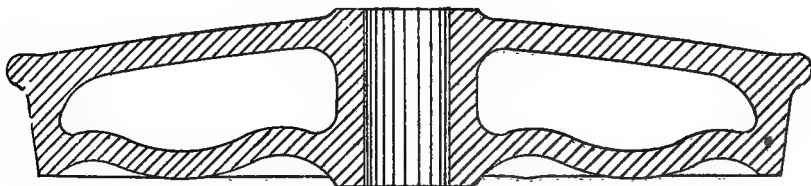


Bush & Lobdell Double-Plate Wheel.

Wilmington, & Baltimore Railroad for twenty and twenty-two years. These wheels were not pitted or cooled in sand, or annealed by any other process. The strain or tendency to crack was compensated for by the curved plates.

In 1844, E. A. Lester obtained a patent for a single-plate wheel, having a waved plate. This form of wheel has never been successful on steam roads. It has been, and is now, extensively used under horse-cars, on account of its lightness.

In 1845, George W. Eddy, of Waterford, New York, patented a wheel with the inside plate convex, the other undulating or waved, and a solid or undivided hub. These wheels did not require pitting or annealing, the plates yielding as the parts contracted, and when



G. W. Eddy. December 26, 1845.

made of good material were strong, and if properly chilled wore well and gave good satisfaction. Other wheels, both single- and double-plate, with waved and corrugated plates, some with brackets on one, and some on both sides, were patented by several parties, but all constructed so that the plates would bend or yield to allow for the unequal contraction. These proved unsatisfactory, and therefore did not come into general use.

On April 17, 1847, Mr. Sizer patented a wheel, the hub connected with the rim by two curved plates, both plates concave on the out-

side. The manufacture of this wheel led to the great patent suit of William V. Many *vs.* Sizer, which was decided in favor of Mr. Many, who had become the owner of the patent of Truscott, Wolf, & Dougherty, and which sustained the claim that all wheels made with curved plates and in one piece were infringements of that patent.

In May, 1847, Anson Atwood patented a wheel, described in his claim as follows: "Connecting the rim of the wheel cast in one piece, with a solid hub, by the combination of a ring made of radial waves, in combination with the dished flange or flanges of the hub, which forms a rim concentric with the rim of the wheel, substantially as described, whereby the several parts can yield to unequal contraction in all directions, without serious strain of the metal, as described." These wheels were used to some extent, principally for freight-cars, and were generally pitted or covered in sand. They were subject to the objection common to all wheels which have plates with corrugations extending to the rim and uniting with it at points equally distant from the flange or rail line. This causes the chill to be of unequal depth and hardness at different points of the same section of the tread, occasioning them to wear more rapidly in one place than in another.

Prior to 1847 or 1848, the pitting or gradual cooling of wheels by covering them in sand, or placing them in a heated oven, was not practiced; consequently all plate-wheels had to be made with the plates curved, so that they would yield and accommodate the different parts to the unequal contraction. The process of cooling is by most wheel-makers termed annealing, which is a misnomer. To anneal is to "heat nearly to fluidity," etc. A degree of heat much below fluidity applied to a wheel will soften the chill so as to render it unfit for use. The necessity for the process is this: the tread and the parts of the plate or plates farthest from the hub cool most rapidly and shrink first, consequently the shrinking of the hub and parts of the plate or plates next to it which takes place afterwards, produces a strain, which ruptures the plates, and causes the wheel to break. To prevent this, various expedients have been resorted to. Some passed a current of steam or water through the hole in the hub; some placed the wheels in a pit on a bed of sawdust or fine charcoal, and put sawdust or charcoal between them on the plate; and others put them in pits and passed a current of air through the hole in the hub. This last process was used by Bush & Lobdell, in 1847 or 1848. At the same time dry sand or ashes were applied to the rim and plate, but this was abandoned, because it was found that when the wheels were removed from the pit the rims were hotter than the hubs. They

then tried covering them in hot dry ashes, and afterwards in hot sand, which was found to answer equally well. This process was also used about the same time by Mr. Washburn and others, and it is now used by almost all wheel-makers. The effect of this process is as follows: Iron being a good conductor of heat, and sand a poor conductor, the extra heat which is in the hub and other parts when the wheel is covered is imparted to the colder parts; and as the sand prevents a rapid cooling, all parts cool, and consequently shrink, alike, thus relieving the wheel from any strain that would result from one part cooling and shrinking before another.

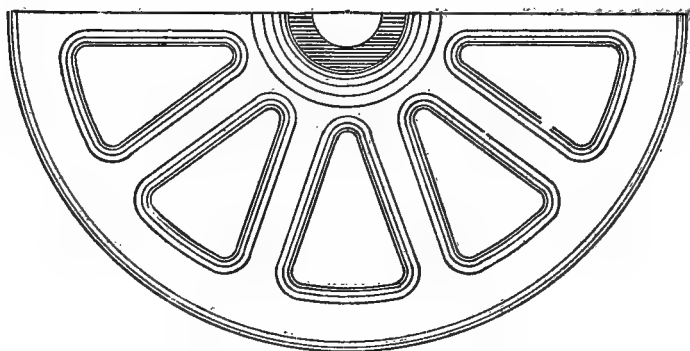
In 1848, Asa Whitney, of Philadelphia, invented a process of annealing or cooling wheels by placing them in an oven and heating them, then allowing them to cool slowly. The first wheels cast by him, and so annealed or cooled, had a single corrugated plate. In 1854 he made the plate straight, or nearly so, with brackets on the inside, connecting the hub and rim. Of this form the firm of A. Whitney & Sons have cast and continue to cast large numbers. Mr. Whitney's first experiments, like those of others at that time, were made by forms of pattern which would yield to the unequal contraction in cooling, and thus neutralize the strain; and he patented several forms of wheel for this purpose, but none of them proved successful. The experiments in this direction, however, led to the process of slow cooling, or annealing, for which a patent was granted to him, April 25, 1848. The patent may be briefly described as follows:

"A process for annealing and cooling chilled cast-iron car-wheels, consisting in removing the wheels from the moulds before they have cooled sufficiently to produce any inherent strain on any part, and immediately depositing them in a previously-heated furnace or chamber and raising the temperature to a proper point, below fusion, and then allowing them to cool so slowly that all the parts of each wheel shall cool and shrink simultaneously." This process was a great discovery in wheel-making, and, although for some years afterwards others were experimenting in and patenting forms of pattern to overcome the unequal contraction in cooling, the great advantages of the slow cooling and annealing process gradually became so apparent by experience, that all wheel-makers eventually adopted it in effect.

On August 7, 1849, J. Murphy, of Kensington, Pennsylvania, obtained a patent for a mode of cooling wheels with solid hubs, which was "to remove them from the flask and chill as soon as possible, and place them in a case of brick-work or other non-conductor or bad conductor of heat, which case is so formed as to inclose all the wheel except the hub. . . . The joints of the case around the spokes

of the wheel are made air-tight by means of sand, clay, or similar substance."

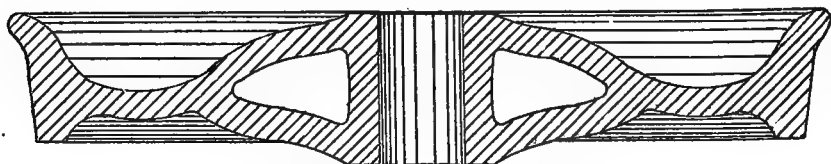
In 1849, Thomas S. Bourshett patented a wheel having a hollow hub and rim, connected with hollow spokes. This form of wheel



Wheel with Hollow Spoke and Rim.

was made about the same time by Mr. Mason, of Taunton, and used under trucks of the engines built by him; it was preferred on account of its neat appearance, and because the inside box could be oiled through the spoke; but, being a difficult wheel to cast, it has never been much used, except under trucks of engines, and to a limited extent under tenders.

In 1850, Nathan Washburn patented a wheel, having a double plate at the centre, and a single waved plate at the rim, with brackets or



N. Washburn. October 8, 1850.

braces supporting the tread on the inside of the plate. This form of wheel is very strong, and is now used almost exclusively whenever double-plate wheels are required. These wheels have to be cooled gradually, to allow for the contraction, which is done by covering them in dry hot sand.

In 1850, George W. Eddy invented and patented a wheel, having the hub connected with the rim by a single plate on the outside, and wrought spokes on the inside. This wheel was lighter, and was sold for a less price than the double-plate wheel; it was strong, and on

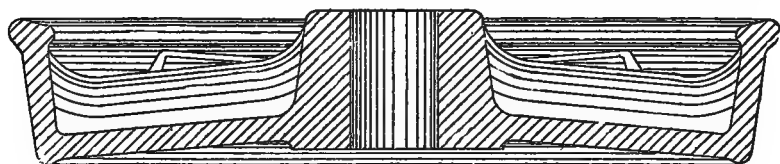
account of the manner in which the iron ran when the rim or tread was formed, was chilled deeper and harder, and had a more lasting chill than any other form. A 30-inch wheel of this form that had run on the Richmond & Danville Railroad for twenty-five years, and several which had run on the Philadelphia, Wilmington, & Baltimore Railroad twenty years and over, were exhibited at the Centennial Exhibition by the Lobdell Car-Wheel Company. The objection to this wheel was that the wrought spokes have a tendency to make the hub on the side to which they were attached, hard and difficult to bore, and car-builders and others who had their work done by piece-work complained that they could not bore them.

From 1849 to 1860 the minds of many were directed in a remarkable degree to perfecting railroad-wheels. During this period no less than eighty-eight patents were granted for alleged improvements, which consisted of making the plates of all conceivable forms, having curves and contortions that must have greatly exercised the ingenuity of patent agents to describe, as is shown by a few quotations from some of the claims, as follows: "Arch piece *b*, and the hollow annulus *c*, and the solid annular parts *d* and *f*;" "spokes, single-plate and double-plate combined;" "single-plate with curved arms thereon, reversed to the right on one side, to the left on the other;" "auxiliary or zigzag rims in said annular space;" "with a rim *c*, of the form of a semi-ellipsis, and of an oblate spheroid *b*, with braces *d*, of the form of *cyma-reversa* and *cyma-rectas*," etc.; wheels with "sunk and raised panels;" wheels with "the multiplied and reversed or alternate corrugations of the plate or flanges," etc. None of the patents granted during this period, excepting those of Bourshett, Washburn, and Eddy, were of any importance, as they did not add to the strength or durability of railroad-wheels.

In 1853 street railroads were opened in New York, though prior to this the New York & Harlem Railroad Company had conveyed passengers on their road in cars drawn by horses. In 1857 they were opened in Philadelphia and Boston, in 1859 in Pittsburgh, and in 1860 in New Orleans. The cars used on these roads required light wheels with narrow treads, which have been almost universally made with a single plate, or with spokes of wrought- or cast-iron, the single waved plate being used by all wheel-makers, excepting Whitney & Sons, who make a wheel with a straight plate, and the Lobdell Car-Wheel Company, who make a wheel with a straight plate, with the addition of a rib on the inside of the tread, opposite to the flange. The latter also make a wheel with waved plate if desired. To meet the demand for a light wheel for horse-cars, wheels have been made by a few wheel-

makers having a cast-iron hub and rim, and wrought staggered spokes; but they are difficult to cast and are expensive, and on this account have not been generally used. Light wheels for horse-cars are made by removing a part of the plate between each bracket or brace. It has been found by the Lobdell Car-Wheel Company that better wheels can be made, admitting a harder and deeper chill, by making them with cast arms or spokes, and of such shape that there will be no thin parts or edges to chill and cause them to crack. Wheels of this pattern were shown by them at the Exhibition, and they will bear chilling deeper than the light plate-wheels used for horse-cars.

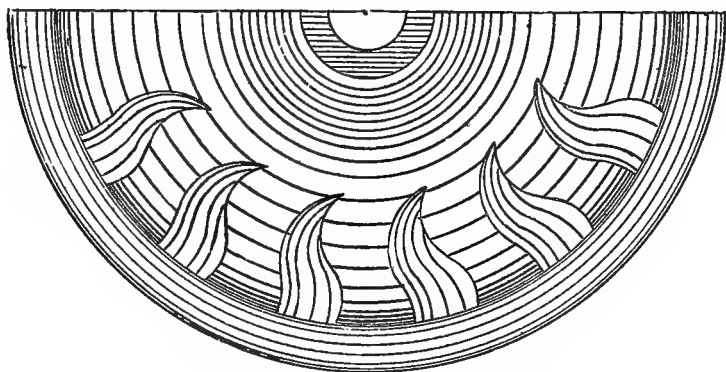
In February, 1861, George G. Lobdell patented what is known as "Lobdell's improved single-plate wheel," which differs from those



Lobdell's Improved Single-Plate Wheel.

made by others in the addition of a rib to the inside of the flange, which not only adds to the strength of the wheel, but has a tendency to make a more perfect chill at or near where the flange commences. In many wheels made without this rib the chill at this point is less in depth than at other places, and the flange, when worn sharp, is more liable to break.

Mr. George G. Lobdell also patented in January, 1869, the wheel known as the "Lobdell combination wheel," which is similar to the



Lobdell's Patent Combination Wheel (side view).

Washburn wheel; it is the Washburn wheel with the addition of a

rib to the inside of the flange, and has the same advantages as the single-plate wheel. This wheel is very strong, cannot be broken in



Lobdell's Patent Combination Wheel (sectional view).

fair use if made with proper care and properly cooled, and can be as perfectly chilled as any form of wheel cast with the flange down.

In 1843, T. Perkins and W. McMahon, Baltimore, Maryland, obtained a patent for the method of fastening chilled tires for driving-wheels to the centres. The centre was turned conical, larger on the inside, the taper being about $\frac{1}{4}$ inch in 4 inches; the tire was held on by means of "gibs," placed in slots cut in the periphery of the centre, the gibs having a head on one side, which bore on, and fitted into, notches in the outside edge of the tire, while there was a nut on the inside end of the gibs. The idea was that the tire might stretch and require to be tightened, which was to be done by means of these nuts. This was found not to be necessary, because when properly fitted they never required tightening, and the nuts were not used. The gibs, when used, were put on hot and riveted on the inside end. The use of gibs was soon abandoned, and the tire was secured by bolts through the rim of the centre, which were either tapped into the tire a short distance or fitted into a recess in the tire. These tires were used for many years on the Baltimore & Ohio, the Pennsylvania, the Philadelphia, Wilmington, & Baltimore, and other railroads, both for passenger- and freight-engines, and are now used extensively on these roads under shifting-engines. When made with care, of the proper material, and selected so that the tires under an engine are of uniform diameter, they give a very great mileage. A tire made by Bush & Lobdell, and shown at the Exhibition by the Lobdell Car-Wheel Company, ran on the Richmond & Danville Railroad for fifteen years.

Until within a few years chilled wheels were made entirely of charcoal pig-iron, having proper qualities of chilling and strength, and of which there is a comparatively limited production, as all iron made with charcoal is not suitable for making chilled wheels. The increase in our railways, and the consequent increased demand for chilled wheels, raised the price of charcoal wheel-iron to a high figure and the wheels to a high cost. Under this state of things, William G. Hamilton, of the Ramapo Wheel Company, Ramapo, New York, began to experiment, with a view to discover a mode of using iron

cheaper than charcoal wheel-iron, the result of which was that he found that steel, particularly Bessemer steel, melted in a cupola or other furnace with pig-iron, added strength and chill to weak and partially- or non-chilling iron. For this a patent was granted to him December 22, 1868, and reissued February 25, 1873. About December, 1871, A. Whitney & Sons, wheel-makers, of Philadelphia, began to experiment under Mr. Hamilton's patent, and obtained such satisfactory results in a few months' trial that they decided to use the mixture of steel with pig-iron at their works, under license from Mr. Hamilton's company. At that time, but a limited quantity of rails of Bessemer steel (which is best for the purpose) could be had in this country, as but few steel rails had been worn out, and it became evident that a demand for Bessemer steel scrap, from a few wheel-makers, would raise the cost of such metal higher than that of charcoal pig-iron. Experiments were therefore made in 1872 by A. Whitney & Sons with wrought-iron rail scrap, as a substitute for Bessemer steel, and it was found to add strength and chill to pig-iron, the same as Bessemer steel. A patent was granted to George Whitney July 16, 1872, and reissued November 5, 1872, for the use of wrought-iron in chilled wheels. The patents of Mr. Hamilton for steel, and of Mr. Whitney for wrought-iron, in chilled wheels, are now the property of "The Hamilton Steel Wheel Company, of Philadelphia," under licenses from which a very large number of wheels have been made and are now made in this country.

The discovery of the advantages of steel and wrought-iron in the manufacture of chilled wheels seems second only to that of the slow-cooling and annealing process. The use of steel and wrought-iron has been the means of rendering available many brands of pig-iron less costly than charcoal pig, thus greatly reducing the cost of wheels to the consumer, and at the same time enabling the manufacturer to produce a stronger and more durable wheel than is possible by the use of pig-iron alone.

For several years past many of the wheels used under engines, tenders, and passenger-cars have shown defects of a character which did not occur before, and which are termed scabs, or blotches. Wheels of small diameter are more liable to have them than those of large diameter; and this liability also attaches to wheels used under heavy engines and tenders, and heavy cars that run at high speed. They have been more common since the introduction of the air-brake, occasioned, no doubt, by the severe grinding or abrading action on the surface of the wheels, which takes place in stopping the momentum of the train in the exceedingly short distance in which it is

now done, by the use of the air-brakes. There appear to be incipient defects on the surface of the wheels, which do not extend to a great depth into the chill, but which the constant and repeated concussions of the wheels on the rails, or the slipping of one wheel when in motion (no two wheels ordinarily being of exactly the same diameter), develop into these blotches or scabs. What occasions these defects is a moot question among wheel-makers. They do not appear on the surface, and cannot be detected by any examination before being used; they are seldom found in wheels which have not a hard and deep chill. To determine to what depth they extend into the chill, and whether they would continue to be developed when in use, Mr. William W. Lobdell, of the Lobdell Car-Wheel Company, in April, 1875, caused a pair of 26-inch truck-wheels, that had been used eleven and a half months on the Philadelphia & Baltimore Central Railroad, to be turned. These wheels showed a number of blotches, which were all removed by turning. They were then put under one of the heavy engines used on the Philadelphia, Wilmington, & Baltimore Railroad, where they were constantly in use until removed to be placed on exhibition at Philadelphia, having made 28,600 miles after the treads were turned. They are not worn out, but will be again used on the same road; they show no blotches or defects, and to all appearance may yet make 50,000 miles. This experiment led to turning off many others with the same success. As yet none have been in use long enough to be condemned, and none show defects of this character, proving that the defects, however occasioned, do not extend much below the surface. It also led to turning off new wheels, and established the fact that, however much care is used in the preparation of the chill, no chilled wheels are perfectly cylindrical or of uniform diameters. By turning, these incipient defects are removed, the wheels are made of a uniform diameter and cylindrical; consequently there is no tendency to slip, and the wear is greatly diminished.

Mr. George G. Lobdell has recently invented, and put in use, in the shops of the Lobdell Car-Wheel Company at Wilmington, a lathe arranged to turn chilled wheels on the axle. With this lathe many wheels, heretofore condemned and sold as old material, on account of flat places in them, caused by sliding, can for a small sum be turned and made better than they were before. Wheels that are chilled to the proper depth, say five-eighths to three-fourths of an inch, may be turned more than once. It is believed that once turning will increase the mileage fully 50 per cent.

ELLIPTIC SPRINGS.

BY FELICIAN SLATAPER.

A brief and condensed report of railway springs from their first application and use in the United States, shows that the first in use were the leather or "thoroughbrace" springs, dating back to 1829 and 1830. The motion imparted by these springs to the coach body was principally a rocking movement with something of a lateral motion combining to give some relief, but accompanied upon rough tracks with an abrupt termination, which soon suggested the necessity of more elastic perpendicular motion.

Soon the same class of coach bodies which was running on four wheels was fitted with pedestal frames, with pedestals or " housings" for the axle-boxes. Above these frames, and between them and the bodies of coaches, four imported full elliptic springs were placed, each being directly (or nearly so) over the axle-box. These springs were quite correct in design, but could not furnish to the coach body the lateral motion required, which the former leather springs developed to some extent, nor could they neutralize the uncomfortable movements imparted by the road directly to the frame beneath. These defects soon developed the necessity of combining within some independent wheel-frames the springs and leverages necessary to absorb the abrupt motions from the road, and resting the coach body upon this last system of springs and levers. As early as 1829 the "bogy," or four-wheeled truck, was adopted; and the lateral movement (almost universally used at the present time) known as the swinging bolster, was applied soon after. These principles seeming to be the perfection, practically and economically considered, of railway car-trucks, it remained only necessary to develop the proper arrangement, and then the most perfect construction of the various most approved railway springs then in the market.

Many car-trucks were as early as 1840 fitted with coiled or spiral springs, constructed of either flat or round steel of various grades of high or low carbonized steel. First, the trucks were without what are known as equalizing bars reaching from axle-box to axle-box. This allowed springs to be placed upon them, which received the first shocks from the road at points near to or removed from the axle-boxes, and on some lines the springs were placed on the exact centres of these bars.

The necessity, in the earliest forms of car-trucks used, of placing the springs directly over the axle-boxes developed a class of springs

which, while capable of resisting the shocks, reacted in an unpleasant jumping motion, frequently repeated too often to allow of either comfort or absolute safety. This soon led to the adoption of equalizing bars, which allowed the movement of the axle-box and the springs to be relatively changed, and so adjusted as to give the springs a leverage and make their movements easier. The improved feature of equalizing bars being now adopted, it remained to develop the combination and proportions of springs which should insure the best results.

As early as 1844-45, rubber properly vulcanized for railway springs was applied; and it developed, especially in the trucks with equalizing bars and swinging bolsters, a remarkable quality of absorbing or neutralizing the noise and jarring motion of the springs of various materials then in use.

Many admirable qualities attach to rubber springs, and were it not for the effects of climatic changes upon them, and the difficulty of restraining their tendency to bounce upon receiving sudden shocks from the road, they would be desirable for exclusive use under car bodies. They still retain qualities making them desirable in combination upon equalizing bars with steel springs, and are often used in this way.

The hasty construction of railways, and consequent roughness of the tracks, made it necessary to develop some combination and character of springs suited to that condition, possessing the utmost durability that was possible, and as great economy as the roughness of the tracks would allow.

Up to this time, while the arrangements of the trucks were quite perfect, but little progress had been made in developing first-class elliptic springs, and those in use were constructed upon principles so contrary to correct theories that they required great quantities of steel to "hold up," and concentrated their action so much at particular points in the springs that not only was their motion almost completely destroyed, but their repairs, if any motion was developed, were constant and expensive. These conditions encouraged the continued use of inferior forms of springs, which were, however, from their inception, far more correctly constructed than the elliptics of that date.

The features of elliptics which make them unapproachable as springs are their slow motions to an almost unlimited extent, with their power of absorbing many disturbances in one motion, and the time they take to recover without abruptness from the immediate effects of such disturbances. The roughness of the common highways has made their use on all classes of vehicles imperative, and the

same reasons prove conclusively that this form of spring can never be displaced or equaled upon railways until the common highways of the country can point to some other successful form of springs in use upon their surfaces.

A most creditable advance has been made upon American railways in the adaptation of springs comprehending the proper number of elliptics and their best arrangement, and this branch of railway equipment would now be in the very front of progress were it not that a great many trucks of early design are in process of wearing out previous to abandonment.

It is unnecessary to speak particularly of locomotive springs, further than to affirm that in their earlier uses the same defects of form existed as in car springs, and modification of the designs in the engines became necessary to meet the requirements of the improved springs now so generally and successfully used.

Of the use of elliptic crucible steel springs in freight-cars, it may be said that the high cost of this steel in the earlier applications made it necessary to construct short springs to keep the cost per car at a point to favor their introduction. Their action even under these unfavorable circumstances was so satisfactory as to encourage and procure the use of longer springs, which has also been favored by the reduced cost of crucible steel.

At the present time many of the leading lines whose cars are subjected to heavy service, both in mileage and loads, have adopted crucible steel elliptic springs of sufficient length and capacity for their freight-cars to insure durability beyond the life of the cars, and sufficient range of motion to make the cars safe at the highest rates of speed, and easy upon the roads with the heaviest loads.

IMPROVEMENTS IN BRANCHES OF THE PENNSYLVANIA RAILROAD.

BY FELICIAN SLATAPER.

Railways, or tram-roads, date back about two hundred years before the first introduction of steam-roads in this country. In fact, the locomotive appeared one hundred and ninety-nine years after the first tram-road in the coal regions of England and Wales, where a Mr. Beaumont received the credit, in 1630, of laying the first wooden rails for the transportation of coal. From that time improvements have been made, but very slowly at first, for it does not appear that iron rails were used until some hundred years after the year 1738; and the first

locomotive was tried on rails in 1804. This was Trevithick's tram-engine, which, after running off the road, was degraded, and worked out its existence as a stationary engine about twenty years before the time of any of the rail- or tram-roads of this country.

At that time, however, it would not have been said to be "degraded;" since, for a quarter of a century after, there seems to have been great doubt whether stationary power, at intervals of three miles, with endless rope, would not be better, and it was not until after that date that the locomotive was considered more practicable.

The State of Pennsylvania has the credit of the first locomotive used in this country, which was imported from England in 1829, one year before any were built in this country. And in August, 1831, the "John Bull," which was shown in the Exhibition, was received at Philadelphia,—not the "John Bull" of the Mohawk & Hudson Railroad, which is so often pictured as the "first steam-train of America." The locomotive "John Bull" was built by Roberts, Stephenson, & Co., at Newcastle-upon-Tyne, England, for the Camden & Amboy Railroad, arrived at Philadelphia, August, 1831, and was transferred to Bordentown, New Jersey, September 4, 1831. The original dimensions of this locomotive were 9-inch cylinders, with 20-inch stroke, one pair of drivers 4 feet 6 inches, and one pair of wheels 4 feet 6 inches, not connected. The hubs of the wheels were of cast-iron, spokes and felloes of wood, and tires of wrought-iron. Its total weight was ten tons. The engine was transported from Philadelphia in a sloop, and transferred by means of wagons to the tracks of the Camden & Amboy Railroad, at the Bordentown shops. The machinery was there put together, and a tender was constructed with whisky-barrels upon a four-wheeled platform-car, which had been used by the contractor in the construction of the road. The connection between the pump of the engine and the crude tank thus formed was made by means of a leather hose, fitted up for the purpose by a shoemaker in Bordentown. The locomotive was first run by steam on September 15, 1831; and several trips were made before the first public trial, on November 12, 1831, when the members of the New Jersey Legislature and a number of other prominent persons were among the guests present. The general instructor and conductor of the train was Robert L. Stevens, with Isaac Dripps, engineman, and Benjamin Higgins, fireman. The "John Bull" remained at Bordentown until 1833, when the Camden & Amboy Railroad Company began running their cars by steam-power, the road having been previously operated by horse-power. The road was completed through to South Amboy in 1834, at which time this locomotive was placed in regular service, and con-

tinued in successful operation until 1866. As it was the first engine on the road, care was taken to preserve it, using it only as a curiosity, and since the lease of the New Jersey roads to the Pennsylvania Railroad it has been kept as a relic. This locomotive, together with the two cars placed on exhibition, were photographed some time ago, to represent the early rolling-stock of this country. The cars are of the following dimensions: 38 feet 4 inches from out to out of draw-bars; 8 feet 7 inches in width; height from rail to cornice, 10 feet 1 inch; from rail to top of car, 11 feet 1 inch. The construction of the cars was remarkably good, as they were thoroughly trussed. They originally had the doors on the side, without steps, as, at the time they were in use, the station platforms were sufficiently elevated to avoid that necessity. The seats were covered with cloth, and in lieu of blinds curtains were used.

To note the advance in rolling-stock of railroads in the half-century hardly passed, it is only necessary to compare this exhibit of the Pennsylvania Railroad (the first train of the Camden & Amboy Railroad) with their present standard locomotives, as constructed from their drawings, by Mr. J. B. Collin, Mechanical Engineer, and exhibited by the Baldwin Locomotive Works. There were two on exhibition,—the one a standard “C” engine, designed for passenger traffic, and the other a standard “I,” for freight traffic. The passenger locomotive, known on the Pennsylvania Railroad as the “C,” is an eight-wheeled engine of the ordinary American type, and differs from the usual construction merely in some few of its details.

BOILER.—The boiler, which is of the wagon-top variety, is made of soft crucible steel, double-riveted throughout. It differs from the usual construction merely in these points,—in having long stay-bolts extending from side to side between the crown-bars; in having stays passing across the boiler between the tubes, supporting the flat sides of the slope (the part of the boiler which forms the connections between the fire-box and the barrel of the boiler); in having the water-grate formed out of heavy wrought-iron tubes, one and seven-eighths inches diameter,—this kind of grate is used on some other roads,—and in the device for the consumption of smoke. The smoke-burning arrangement consists of a deflector formed out of large tiles supported upon four pipes, which are bent in a suitable manner, and extend from the throat to the crown-sheet.

FRAMES.—The frames are of the usual American construction, being formed out of bars four inches wide by two and one-half inches deep; the pedestals being welded on solid, as already stated, there is nothing peculiar about them, unless it be the manner in which the

two parts of each frame are joined together. With most builders it is customary to carry the forward bar straight back against the front leg of the forward pedestal; and to bend down the top bar of the main portion of the frame, and bolt it to the front bar, thus forming a right-angled triangle, of which the top bar of the main frame is the hypotenuse. The result of this arrangement is that, when the strain comes upon a frame in this manner, the bent portion will yield, or spring, as it is called, and all the strain will come upon the straight part (often upon a single bolt), and this part will soon break its fastenings; after which the bent part of the frame is very apt to break also; in other words, the frame will break in detail because the parts do not "work together." In the Pennsylvania Railroad engine, the front bar, where it joins the main frame, is bent down so as to form an isosceles triangle with the top bar of the main frame; and the result is that the two parts spring alike,—*i.e.*, work together; and not a single instance is known where a frame made in this manner has broken (except in case of a bad weld), although many hundreds are in use.

CYLINDERS.—These are of seventeen-inch diameter, with twenty-four-inch stroke. They were designed some ten years ago. Perhaps their most important peculiarity is that they are symmetrical and interchangeable, so that one pattern will answer for both sides without alteration, the main steam and exhaust openings being central. The cylinders are bolted together in the centre, one-half of the saddle being cast solid with each cylinder.

FOOT-PLATE.—The foot-plate is made of cast-iron. Its peculiar feature is that it has heavy flanges projecting downwards inside the frames, and is secured to the frames by means of horizontal bolts through these flanges. In this manner a fastening is obtained which is an improvement on the old practice.

DRIVING-WHEELS.—The design of the wheels was made some eleven years ago, and has been well tested. The centres, which are made of cast-iron, have hollow spokes, which are counterbalanced with lead; the tires are three inches thick, the driving-wheels are sixty-two inches in diameter.

BRIDGE-PIPE.—This name is given to a contrivance used for the collective supply of steam to the various small fittings which have usually a direct and independent connection with the boiler. This arrangement has been in use on the Pennsylvania Railroad for a number of years, and by this means the making of a number of small openings in the boiler is avoided.

VALVE-MOTION.—This is of the most common kind, consisting of

shifting links and rocker-shafts, which transmit the motion to the valve.

BRAKE.—The engine is fitted with the Westinghouse air-brake on both tender and driving-wheels.

SCOOP.—The tender has a scoop for picking up water while running. This scoop is made substantially upon the same plan as that originally invented by Ramsbottom; but some change in the arrangement and manipulation was found to be necessary in order to accommodate this ingenious contrivance to the American practice. In England, the scoop is let down before the engine reaches the trough, and when it comes over the trough the rails gradually sink down to a lower level, and the scoop is thus made to dip into the water, and in a similar manner comes up at the end of the trough by the rails gradually rising back to their former level. In America this plan was not practicable, owing to the interference of the "pilot," which would strike the trough if the rails were lowered, and it therefore became necessary to make such an arrangement as would allow the scoop to be let down and taken up while the engine was over the trough. This was accomplished by counterbalancing the weight of the scoop and the greater portion of the pressure of the water by a strong spring; and after a little practice neither end of the trough was ever struck by the scoop.

THE FREIGHT-ENGINE.—The freight locomotive exhibited, known on the Pennsylvania Railroad as the "I," is constructed upon a plan similar to the consolidation type of engines, of which the Baldwin Locomotive Works exhibited one built for the Lehigh Valley Railroad Company; but it varies from the latter in some important particulars, and in some respects it might be called the improved "camel-back," because the boiler of the Pennsylvania Railroad engine is constructed substantially upon the same plan as that of the Winans engine. The reason for the variations in the plan of this engine from the original type was mainly found in a desire to prevent, if possible, the unusually rapid destruction of the flanges of the driving-wheels, which was characteristic of this class of engines. It was believed that this defect was due, in part at least, to an insufficient weight on the ponies and forward driving-wheels. How the weights are distributed on the Lehigh Valley Company's engine I do not know; but in a lot of engines of this kind, built by the Baldwin Locomotive Works after their own design, the weight (with the engine in working order) was about as follows:

On pony-wheels	9,250 pounds.
“ first pair of drivers	16,370 “
“ second “ “	21,280 “
“ third “ “	21,130 “
“ fourth “ “	22,990 “
Total	<u>91,020 “</u>

The total weight of the Pennsylvania Railroad engine is about the same, but it is distributed as follows :

On pony-wheels	12,240 pounds.
“ first pair of drivers	21,580 “
“ second “ “	19,200 “
“ third “ “	19,540 “
“ fourth “ “	19,680 “
Total	<u>91,040 “</u>

In order to obtain this result without increasing the wheel-base, it was found necessary to adopt a plan of boiler which would bring the weight forward. For this purpose no plan suggested itself that was better adapted to the purpose than the “camel-back,” or Winans boiler, which, with slight modification, was found to lend itself with great readiness to the requirements of the design ; and the result, thus far, seems to entirely justify the choice ; as the boiler, besides effecting the desired change in the distribution of the weight, has proved itself a free and economical steamer, and costs less to build than a “wagon-top” boiler of the same power. As to the result of the change of weight in preserving the flanges of the tires, it can hardly be said that nothing remains to be desired, because, where these engines are used on portions of the road having many and hard curves, the flanges will still wear faster than could be desired ; but the difficulty is much lessened, and on the easy portions of the road the flanges of these engines do not wear at all.

PONY-TRUCKS.—Next to the boiler, the most important variation from the original plan is in the pony-truck. This design was contrived for the purpose of getting rid of the springs over the journal-boxes, which prevented the lower portion of the frame from being extended forward to the support of the buffer-beam, and thus left this beam in an ill-supported position. This object was fully attained, and the truck itself appears to work as well as the old one.

MINOR VARIATIONS.—There are a number of other variations in this design, which it would be tedious to enumerate, but I will mention a contrivance for the distribution of the feed-water over the forward portion of the tubes. This apparatus is based upon the following

theory: In a locomotive, as ordinarily arranged, the feed-water sinks down below the tubes, and flows back towards the fire-box, until it encounters the upward current near the tube-sheet, when it is drawn into this current. It thus happens that the feed-water is heated in that portion of the boiler which is most valuable for the generation of steam; whereas, if the low temperature of the forward portion of the tubes could be utilized for this purpose, something of a saving might be attained; but whether any benefit results from this arrangement has not been ascertained.

GENERAL FINISH.—The painting and general finish of the engine is planned with a view to quiet and harmonious effect, and is based upon the principle that the purpose for which a locomotive is used does not admit of any merely ornamental devices; but that its beauty, so far as it may have any, should depend upon good proportions and thorough adaptation of the various parts to their uses.

Pennsylvania took an active part in developing a railroad and canal system of transportation; and in 1834 had a through route from Philadelphia to Pittsburgh:

From Philadelphia to Columbia	.	.	.	.	82 miles, railroad.
" Columbia to Hollidaysburg	.	.	.	.	172 " canal.
" Hollidaysburg to Johnstown	.	.	.	.	36 " railroad.
" Johnstown to Pittsburgh	.	.	.	.	104 " canal.
Total distance					394 "

With the exception of some coal roads, the Philadelphia & Columbia Railroad was the first built in Pennsylvania, and was operated at first by horse-power; and the thirty-six miles of Portage Railroad over the Allegheny Mountains was by a series of ten inclined planes,—worked by stationary engines,—having an aggregate length of 23,169 feet, with elevation of 800 feet rise and 1202 feet of fall.

It was some time after this that the Pennsylvania Railroad was chartered, and commenced building its line west of Harrisburg, which was completed to connect with the Portage State Railroad, at Hollidaysburg, in 1850; and in 1852 the Western Division was completed, giving a through all-rail line between the coast and the waters of the Mississippi, using as the connecting link the old Portage road, with its inclines. This, however, was changed in 1854; and after the building of the new Portage Railroad by the State, all the State improvements were sold out to the Pennsylvania Railroad, and delivered to them on August 1, 1857.

The difference between the old Portage Railroad and the present Pennsylvania Railroad will show the advancement made in railroad

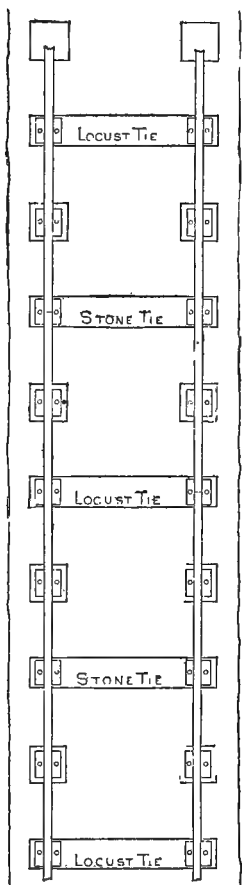
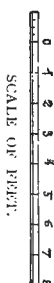
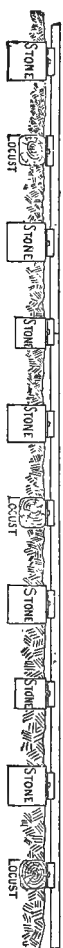
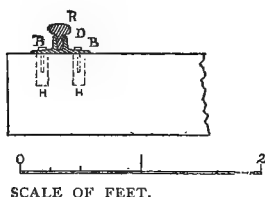


FIGURE I.



SAMPLE OF TRACK OF OLD PORTAGE RAILROAD, 1835.



The shape and style of rail is shown at R. These rails were in length about 15 feet and not very heavy, two men being able to lift one of them. Into holes, H H, wooden plugs were driven, and into these, bolts, B B, securing the chairs to their places. Two wooden pegs, D D, secured the rails to the chairs; two grooves, one on each side, admitted the plugs. The plugs and bolts were continually coming loose, and it was necessary to readjust them after the passage of each train. On curves, short straight rails were used, the sharper the curve the shorter the rail. The ballast was of mud. Ties and blocks, of granite. The New Portage Railroad did away with the stone supports, using in their stead hemlock ties. The rails weighed 83 pounds to the yard.

tracks; the former being the forerunner of the latter, and described by Assistant Engineer G. C. McGregor as follows:

"The old Portage Railroad was built as far back as 1833, and was intended to be operated by horse-power. The original track of this road was very primitive in its construction, being simply of granite, and wooden sills; to which were secured flat rails of strap-iron. This style in time gave place to the more substantial form, shown on Figure 1 of the accompanying drawings, and which may be described as follows: Granite and locust ties, alternating with each other, and separated by granite blocks, served as supports for the rails. The rails, which were of a peculiar pattern, were secured to the supports by cast-iron chairs; the latter being fastened to the supports by bolts driven into wooden plugs, which were forced into holes previously made for their reception in these supports. This fastening was a source of much trouble and inconvenience, the bolts coming out of their places at the passage of nearly every train, necessitating constant attention. The wooden pegs with which the rails were secured in the chairs were for the same reason a source of considerable expense and annoyance. The rails, owing to their very narrow base, had to be supported about every three feet in order to keep them from turning over. This plan seemed to have been thought more economical than to increase the base of the rail, and do away with the large number of chairs. The length of the rail was about fifteen feet, and it was much lighter than those used at the present time."

The idea of bending rails for curves does not seem to have been considered in track-laying; and a curve at that time looked like a portion of a polygon of a decidedly finite number of sides. The builders compromised it by using short rails, the rule followed seeming to have been, "the sharper the curve the shorter the rail." Good ballasting seems to have been a feature of very little importance. The road, when taken by the Pennsylvania Railroad Company, showed that little ballasting had been done. What ballast was used was broken sandstone. Drainage, now considered very necessary, was then thought of very little importance. In fact, the entire road was very primitive, and the rattle and clatter of a train could be heard long before it approached.

Soon after the road came into the possession of the Pennsylvania Railroad the style of track was changed, and in 1859 a chair-joint with hemlock ties was used. Figure 2 will illustrate this, showing about twelve ties to a twenty-five-foot rail, which were found to give longer life to the rail, and cost less. The broad base was afterwards

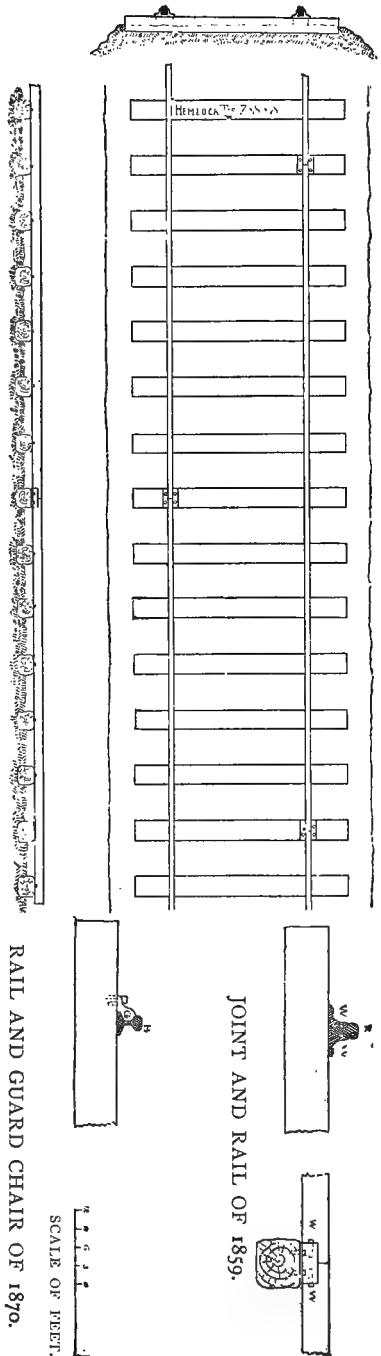


FIGURE 2.

Ties of hemlock, 7' x 8' x 8', twelve to a 25 feet rail. Ballast—sandstone, bluestone, mud, etc. Rail, 64 pounds per yard; shape shown at R; secured in chair by wooden pins, W W. Rail in use in 1870, 56 pound iron as shown at B. Guard chair for curves shown at G.

SAMPLE OF TRACK OF PENNSYLVANIA RAILROAD IN 1859.

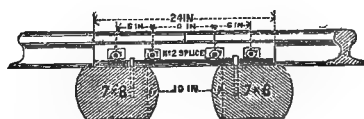
RAIL AND GUARD CHAIR OF 1870.

SCALE OF FEET.
1 2 3 4

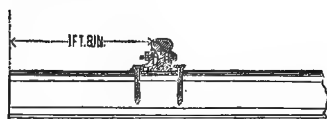
adopted, and spikes were used instead of bolts, as it was found impossible to keep the latter in place. The style of chair then in use allowed the rails to "creep," and to close up at some points and widen out at others. Besides, the joints, coming as they did directly on the ties, caused the rails to be very much battered at their ends. The "fish-joint," in use on one or two roads as far back as 1845, does not seem to have been introduced on the Pennsylvania Railroad till much later. The battering of the ends of the rails was in a great measure obviated by suspending the joint. The "creeping" of the rails was prevented by the introduction of the "stop-chair," of which there are a number of patterns,—one being a piece of plate-iron bent to fit to the fish-plate, and the base of the rail. It is about three inches wide by seven inches long. Its lower end is held to the tie by two common rail-spikes, and its upper end is bolted to the outside of a fish-plate by one of the bolts which confine the fish-plate to the rail. Two chairs are used to a joint,—one at each end of the fish-plate. The angle fish-plate is now used in place of the stop-chair above described, and is found to be a very excellent form, which can be bettered by having the angle-plate on both sides of the rail. This double-angle fish-plate joint is now used on bridges and in tunnels. From the experience of the Pennsylvania Railroad it was found best to suspend the joint; and as stability of the cross-ties at the joints was essential, it was desired to have the road well ballasted, as a "churning" tie will soon destroy the best joint.

Figures 3, 4, and 5 show a section of the standard joint used on the Pennsylvania Railroad, and also cross sections of standard track and ballast. The other drawings show the standard rails and their fastenings; the standard turn-outs, crossings, etc.; there are also given bills of ties for the different turnouts, crossings, etc., and a specification for a standard subdivision.

FIGURE 3.

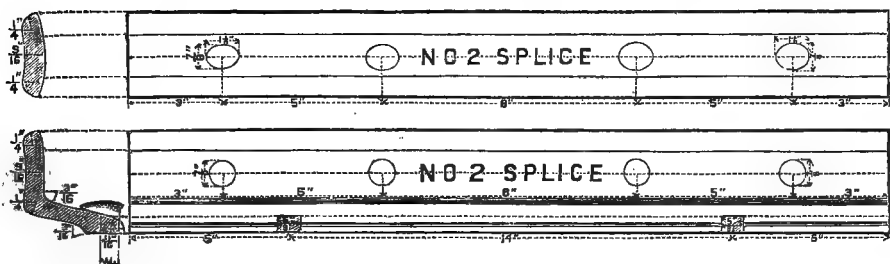
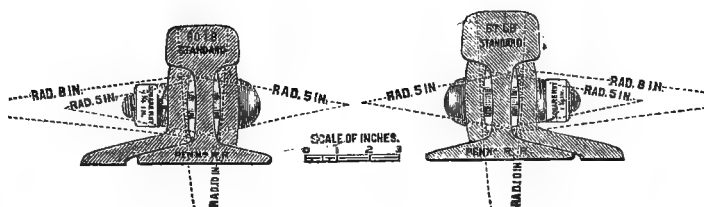


SIDE VIEW OF RAIL JOINT.



CROSS SECTION OF RAIL JOINT.

FIGURE 4.



STANDARD RAILS AND SPLICE ON THE PENNSYLVANIA RAILROAD, 1875.

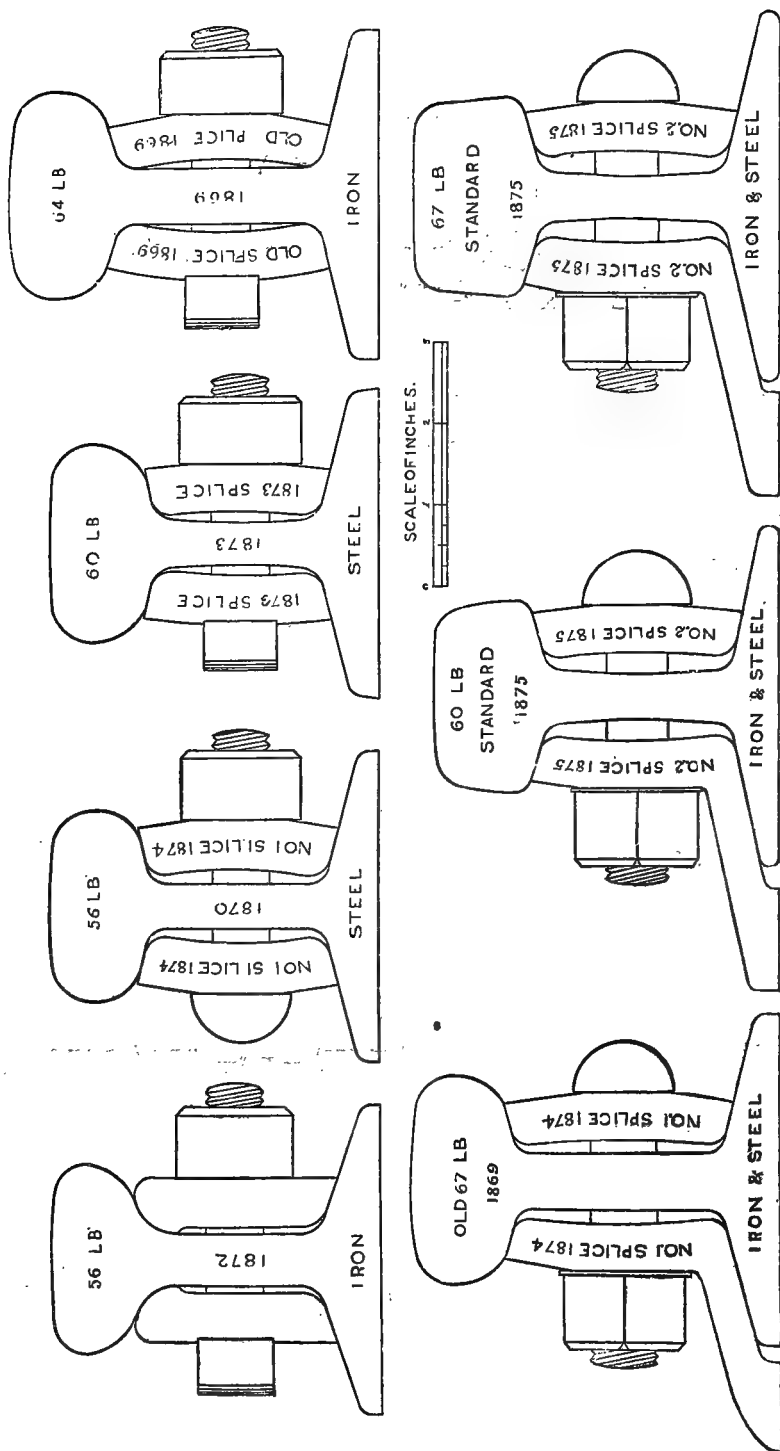
FIGURE 5



CROSS SECTION GRAVEL BALLAST.



CROSS SECTION BROKEN STONE BALLAST.



RAILS AND SPLICES USED ON PENNSYLVANIA RAILROAD AND BRANCHES.

BILL OF TIES FOR SINGLE-THROW SWITCH AND TURN-OUT. PENNSYLVANIA RAILROAD STANDARD.

No. 10 FROG.

NUMBER OF PIECES.	THICKNESS.	FACE.	LENGTH.	NUMBER OF PIECES.	THICKNESS.	FACE.	LENGTH.
5	7 in.	10 in.	8 ft. 6 in.	1	7 in.	10 in.	17 ft. 7 in.
2	"	"	8 " 7 "	1	"	"	11 " 8 "
1	"	"	8 " 8 "	1	"	"	11 " 10 "
1	"	"	8 " 9 "	1	"	"	12 " 0 "
1	"	"	8 " 10 "	1	"	"	12 " 2 "
1	"	"	8 " 11 "	1	"	"	12 " 4 "
2	"	"	9 " 0 "	1	"	"	12 " 6 "
1	"	"	9 " 1 "	1	"	"	12 " 8 "
1	"	"	9 " 2 "	1	"	"	12 " 10 "
2	"	"	9 " 3 "	1	"	"	13 " 1 "
1	"	"	9 " 4 "	1	"	"	13 " 4 "
1	"	"	9 " 5 "	1	"	"	13 " 5 "
1	"	"	9 " 6 "	1	"	"	13 " 6 "
1	"	"	9 " 7 "	1	"	"	13 " 8 "
1	"	"	9 " 8 "	1	"	"	13 " 10 "
1	"	"	9 " 9 "	1	"	"	14 " 0 "
1	"	"	9 " 10 "	1	"	"	14 " 2 "
1	"	"	9 " 11 "	1	"	"	14 " 4 "
1	"	"	10 " 0 "	1	"	"	14 " 6 "
1	"	"	10 " 1 "	2	"	"	14 " 8 "
1	"	"	10 " 2 "	1	"	"	14 " 10 "
1	"	"	10 " 3 "	1	"	"	15 " 0 "
1	"	"	10 " 4 "	1	"	"	15 " 2 "
1	"	"	10 " 5 "	1	"	"	15 " 4 "
1	"	"	10 " 6 "	1	"	"	15 " 6 "
1	"	"	10 " 7 "	1	"	"	15 " 8 "
1	"	"	10 " 8 "	1	"	"	15 " 10 "
1	"	"	10 " 10 "	1	"	"	16 " 0 "
1	"	"	11 " 0 "	1	"	"	16 " 3 "
1	"	"	11 " 2 "	1	"	"	16 " 6 "
1	"	"	11 " 4 "	1	"	"	16 " 9 "
1	"	"	11 " 6 "	1	"	"	17 " 0 "

Total=842 ft. lineal=4911 ft. B. M.

Correct as per Standard Plan.

WM. H. BROWN, *Engineer M. of Way.*

PHILADELPHIA, May 1, 1875.

No. 8 FROG.

NUMBER OF PIECES.	THICKNESS.	FACE.	LENGTH.	NUMBER OF PIECES.	THICKNESS.	FACE.	LENGTH.
7	7 in.	10 in.	8 ft. 6 in.	1	7 in.	10 in.	17 ft. 3 in.
1	"	"	8 " 7 "	1	"	"	11 " 5 "
1	"	"	8 " 8 "	1	"	"	11 " 7 "
1	"	"	8 " 9 "	1	"	"	11 " 9 "
1	"	"	8 " 10 "	1	"	"	11 " 11 "
1	"	"	8 " 11 "	1	"	"	12 " 1 "
1	"	"	9 " 0 "	1	"	"	12 " 3 "
1	"	"	9 " 1 "	1	"	"	12 " 6 "
1	"	"	9 " 2 "	1	"	"	12 " 9 "
1	"	"	9 " 3 "	1	"	"	13 " 0 "
1	"	"	9 " 4 "	1	"	"	13 " 3 "
1	"	"	9 " 5 "	1	"	"	13 " 6 "
1	"	"	9 " 6 "	1	"	"	13 " 9 "
1	"	"	9 " 7 "	1	"	"	14 " 0 "
1	"	"	9 " 8 "	1	"	"	14 " 3 "
1	"	"	9 " 9 "	2	"	"	14 " 7 "
1	"	"	9 " 10 "	1	"	"	14 " 11 "
1	"	"	10 " 0 "	1	"	"	15 " 2 "
1	"	"	10 " 2 "	1	"	"	15 " 6 "
1	"	"	10 " 4 "	1	"	"	15 " 10 "
1	"	"	10 " 6 "	1	"	"	16 " 2 "
1	"	"	10 " 7 "	1	"	"	16 " 6 "
1	"	"	10 " 9 "	1	"	"	16 " 8 "
1	"	"	10 " 11 "	1	"	"	16 " 10 "
1	"	"	11 " 1 "	1	"	"	17 " 0 "

Total=654 ft. 6 in. lineal=3817 ft. B. M.

Correct as per Standard Plan.

WM. H. BROWN, *Engineer M. of Way.*

PHILADELPHIA, May 1, 1875.

BILL OF TIES FOR STANDARD CROSSING. PENNSYLVANIA RAILROAD.

No. 8 FROG.

NUMBER OF PIECES.	THICKNESS.	FACE.	LENGTH.	NUMBER OF PIECES.	THICKNESS.	FACE.	LENGTH.
12	7 in.	10 in.	8 ft. 6 in.	2	7 in.	10 in.	10 ft. 3 in.
2	"	"	8 " 10 "	2	"	"	10 " 4 "
2	"	"	9 " 0 "	2	"	"	10 " 6 "
2	"	"	9 " 1 "	2	"	"	10 " 7 "
2	"	"	9 " 2 "	2	"	"	10 " 9 "
2	"	"	9 " 3 "	2	"	"	10 " 11 "
2	"	"	9 " 4 "	2	"	"	11 " 1 "
2	"	"	9 " 5 "	2	"	"	11 " 3 "
2	"	"	9 " 6 "	2	"	"	11 " 5 "
2	"	"	9 " 7 "	2	"	"	11 " 6 "
2	"	"	9 " 8 "	2	"	"	11 " 8 "
2	"	"	9 " 9 "	2	"	"	11 " 10 "
2	"	"	9 " 10 "	2	"	"	11 " 11 "
2	"	"	9 " 11 "	■	"	"	12 " 0 "
2	"	"	10 " 0 "	21	"	"	20 " 9 "
2	"	"	10 " 2 "	4	"	"	11 " 9 "

Total=1181 ft. 9 in. lineal=6893 ft. B. M.

Correct as per Standard Plan.

WM. H. BROWN, *Engineer M. of Way.*

PHILADELPHIA, May 1, 1875.

BILL OF TIES FOR THREE-THROW SWITCH. PENNSYLVANIA RAILROAD STANDARD.

No. 8 FROG.

NUMBER OF PIECES.	THICKNESS.	FACE.	LENGTH.	NUMBER OF PIECES.	THICKNESS.	FACE.	LENGTH.
1	7 in.	10 in.	10 ft. 0 in.	1	7 in.	10 in.	16 ft. 5 in.
1	"	"	10 " 1 "	1	"	"	16 " 10 "
1	"	"	10 " 2 "	1	"	"	17 " 3 "
1	"	"	10 " 3 "	1	"	"	17 " 10 "
1	"	"	10 " 4 "	1	"	"	18 " 5 "
1	"	"	10 " 6 "	1	"	"	18 " 11 "
1	"	"	10 " 8 "	1	"	"	19 " 5 "
1	"	"	10 " 10 "	1	"	"	19 " 11 "
1	"	"	11 " 0 "	1	"	"	20 " 6 "
1	"	"	11 " 3 "	1	"	"	21 " 0 "
1	"	"	11 " 6 "	1	"	"	21 " 6 "
1	"	"	11 " 9 "	1	"	"	21 " 9 "
1	"	"	12 " 0 "	1	"	"	22 " 6 "
1	"	"	12 " 5 "	1	"	"	23 " 0 "
1	"	"	12 " 10 "	1	"	"	23 " 6 "
1	"	"	13 " 4 "	1	"	"	24 " 0 "
1	"	"	13 " 10 "	1	"	"	24 " 5 "
1	"	"	14 " 2 "	1	"	"	24 " 10 "
1	"	"	14 " 6 "	1	"	"	25 " 3 "
1	"	"	14 " 10 "	1	"	"	25 " 8 "
1	"	"	15 " 3 "	1	"	"	26 " 0 "
1	"	"	15 " 7 "	1	"	"	14 " 8 "
1	"	"	16 " 0 "	1	"	"	.....

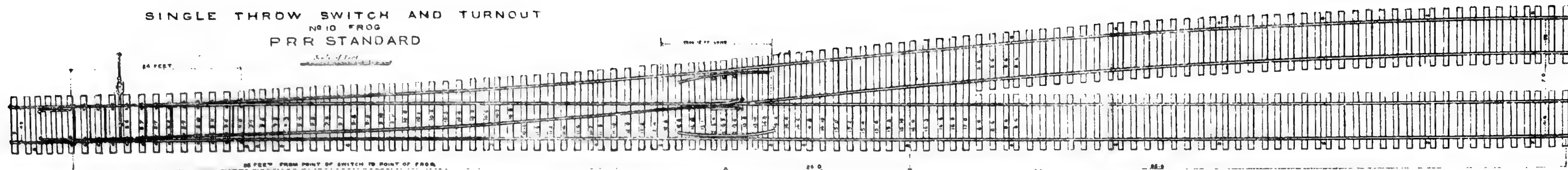
Total=746 ft. 8 in. lineal=4355 ft. B. M.

Correct as per Standard Plan.

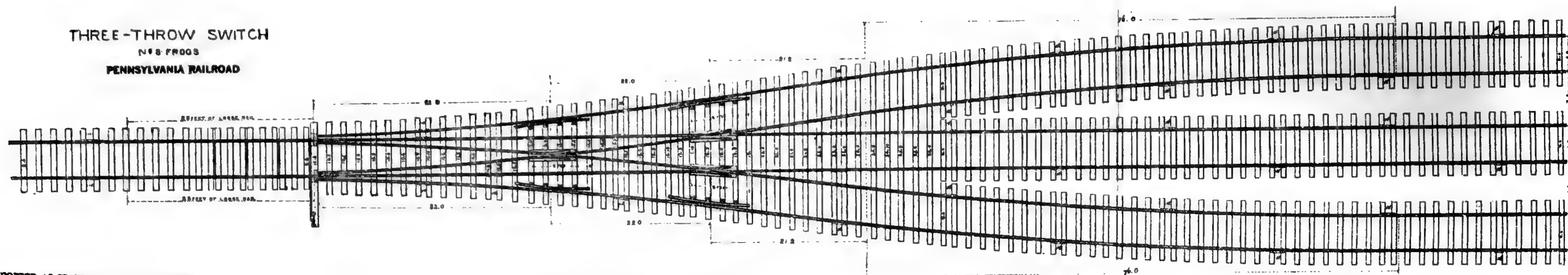
WM. H. BROWN, *Engineer M. of Way.*

PHILADELPHIA, May 1, 1875

SINGLE THROW SWITCH AND TURNOUT
 No 10 FROG
 PRR STANDARD

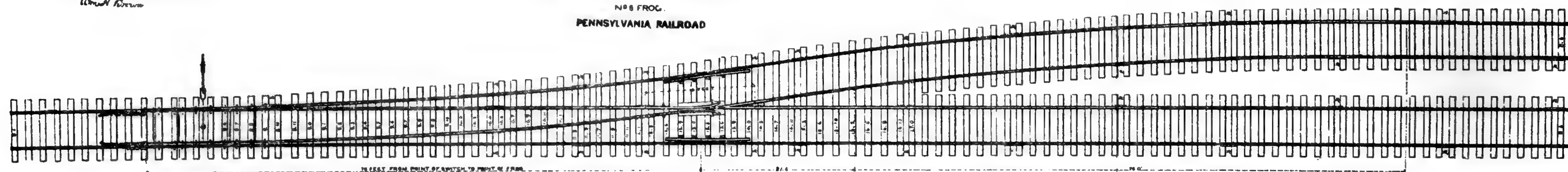


THREE-THROW SWITCH
 No 8 FROGS
 PENNSYLVANIA RAILROAD

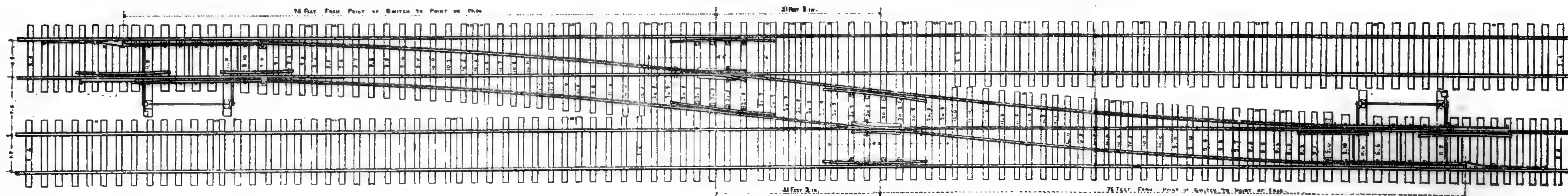


ADOPTED AS STANDARD, JANUARY 1ST, 1875.
 BY ORDER OF CHIEF ENGINEER.
Wm. B. Brown

SINGLE THROW SWITCH
 No 8 FROG.
 PENNSYLVANIA RAILROAD



STANDARD CROSSING
 No 8 FROGS
 PENNSYLVANIA RAILROAD



PENNSYLVANIA RAILROAD COMPANY.

SPECIFICATIONS FOR A PERFECT SUBDIVISION.

SUPERSTRUCTURE.

1. The track must be in good surface; on straight lines the rails must be on the same level, and on curves the proper elevation as set down in the table (to be furnished each subdivision) must be given to the outer rail and carried uniformly around the curve. This elevation should be commenced from 100 to 150 feet back of the point of curvature, depending on the sharpness of the curve, and increased uniformly to the latter point where the full elevation is attained. The same method should be adopted in leaving the curve.

2. The track must be in good line.

3. The splices must be properly put on with the full number of bolts, nuts, stop-washers and stop-chairs. The nuts must be screwed up tight.

4. The joints of the rails must be exactly midway between the joint-ties, and the joint on one line of rail must be opposite the centre of the rail on the other line of the same track. In winter a distance of five-sixteenths of an inch and in summer one-sixteenth of an inch must be left between the ends of the rails to allow for expansion.

5. The rails must be spiked both on the inside and outside on each tie, on straight lines as well as on curves.

6. The cross-ties must be properly and evenly spaced, sixteen ties to a thirty-foot rail, with ten inches between the edge of bearing surfaces at joints, with intermediate ties evenly spaced a distance of not over two feet from centre to centre, and the ends on the outside, on double track, and on the right-hand side going north or west on single track, must be lined up parallel with the rails.

7. The ties must not, under any circumstances, be notched, but should they be twisted, must be made true with the adze, and the rails must have an even bearing over the surface of the ties.

8. The switches and frogs must be kept well lined up and in good order. Switches must work easily and the signals kept bright and clean.

9. Particular attention must be given to avoid low joints at the head-blocks of switches.

10. There must be a uniform depth of at least twelve inches of clean broken stone or gravel under the ties. The ballast must be filled up evenly between, but not above the top of the ties, and at the outer end sloped off to subgrade.

ROAD-BED AND BALLAST.

11. When stone ballast is used, it must be broken evenly and not larger than a cube that will pass through a two and one-half inch ring. In filling up between the tracks coarse, large stones must be placed in the bottom in order to provide for drainage, but care should be taken to keep the coarse stone away from the ends of the ties.

12. The road-crossing planks must be securely spiked; the planking should be three-quarters of an inch below the top of rail, and two and one-half inches from the gauge-line. The ends and inside edges of planks should be beveled off.

DITCHES.

13. The line for the ditch must be well and neatly defined, parallel with the track, at a distance of seven feet from the outside rail; the side next to the track must be made with a uniform slope from the bottom of the ballast to the ditch-line, where it must be at least twenty inches below the bottom of the cross-ties, so as to pass water freely during heavy rains and thoroughly drain the road-bed.

14. The necessary cross drains must be put in at proper intervals.

15. Earth taken from ditches or elsewhere must be dumped over the banks and not left at or near the ends of the ties, but distributed over the slope. Earth taken out of ditches in cuts must not be thrown on the slope.

16. The channels or streams for a considerable distance above the road should be examined, and brush, drift, and other obstructions removed. Ditches, culverts, and box drains should be cleared of all obstructions, and the outlets and inlets of the same kept open to allow a free flow of water at all times.

POLICING.

17. The telegraph-poles must be kept in proper position, and trees near the telegraph-line must be kept trimmed, to prevent the branches touching the wires during high winds.

18. All old material, such as old ties, old rails, chairs, car materials, etc., must be gathered up at least once a week and neatly piled at proper points.

19. Briers and undergrowth on the right of way must be kept cut close to the ground.

20. Station-platforms and the grounds about stations must be kept clean and in good order.

By order of the General Manager.

WM. H. BROWN, *Engineer Maintenance of Way*,
No. 233 South Fourth Street, Philadelphia.

A short section of sample track was built at the Centennial Exhibition, after the present standards, on which the postal cars of the Pennsylvania and New York Central Railroads were placed, just south of the Government Building. This track received favorable mention in connection with the postal cars, and clearly showed the advance in railroads.

The postal car of the Pennsylvania Railroad was one of the limited mail cars, built after a plan of the Post Office Department, to carry the through mail, and was placed on exhibition to show the manner of distributing the United States mails. These cars were sixty-four and one-half feet long, nine feet four inches wide, and were built, with all the interior work, in eleven days.

The request of the Post Office Department, that a fast-mail service be established between New York and Pittsburgh, was made on August 26, 1875, and three cars, each with a tender, were ready for service at Jersey City on September 13. These were built in eleven days after the plans were received, which affords an example of the efficiency of the railroad-shops of the present day.

The interior arrangements of these cars comprise numerous distributing pigeon-holes, of different sizes; the smaller ones, numbering seven hundred, are fitted with reversible bottoms, with labels on each end, the case being made of pine, faced with black walnut; the other boxes are large, and so arranged that, when full, the contents can be taken out from the back. There is also an office in the car containing a writing-desk and chairs, which are convertible into a bed if needed. The foregoing, in connection with closets, etc., make up the

inside arrangements. The exterior of the car is painted white, and varnished, and lettered with gold leaf. The medallion in the centre contains a finely-executed painting of the consulate seal of the United States.

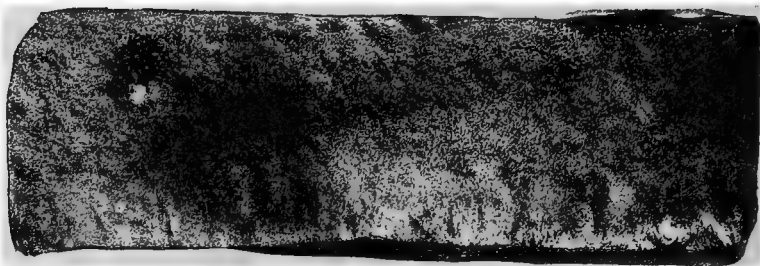
THE HAMILTON STEELED WHEEL PROCESS.

The wheels used under these postal cars were made at the Altoona Wheel Foundry, which took a prominent part in the Hamilton Steeled Wheel exhibit at the Centennial, and under whose patents they were made. This exhibit, although designed to show the great value of the mixture from which the wheels were made, gives a very good idea of the improvements in that branch of railroading.

For a proper understanding of the objects shown by the exhibit, Mr. Hamilton, the patentee, gave a description of the articles displayed, of the plant used in making the wheels, the metals used, results obtained, and reasons for adopting the process.

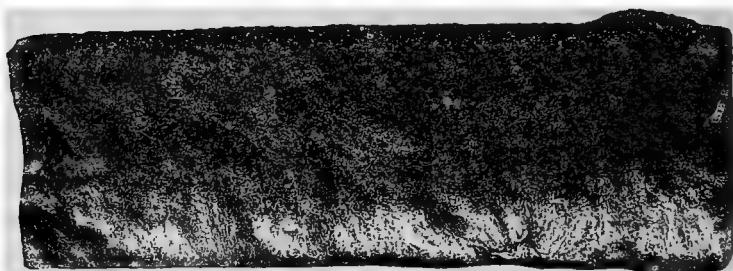
DESCRIPTION OF ARTICLES.—The wheels shown were: Two car-wheels, composed of mixtures of steel and anthracite pig-iron, taken from under Pullman passenger-cars, after making a mileage of 156,800 miles, and still good for service. One of the wheels was broken to show depth and nature of chill.—Three new wheels, of mixtures of steel and iron, to show pattern used.—One engine truck-wheel, which had made a mileage of 140,000 miles, and was good for future service.—One wheel, made of a mixture of twenty-five per cent. steel and equal quantities of anthracite and coke irons. This wheel was very strong, and had a deep chill.—To note the strength of the wheels: one wheel, with eight holes broken through the plate, and one in the hub, driven in by four hundred and twenty-five blows of a thirty-five-pound sledge, the wheel being perfect in all parts except where struck by the sledge—Two cases, containing specimens of various kinds of iron, combined with steel, in varied proportions, to show the increased strength given by the use of steel and chilling properties to non-chilling irons.

The progressive effect of chill and strength was clearly shown in an example of the effect of steel on Glendon anthracite iron, which was made equal in all respects to that of charcoal wheel-iron of the first quality, as is more clearly shown in the annexed photographs:



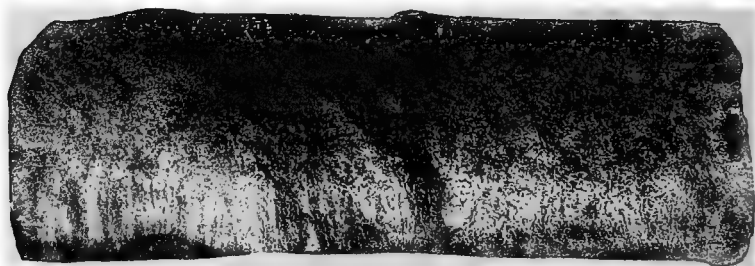
No. 1. ANTHRACITE.

Tensile strength per square inch, 15,167 lbs. Stretch, .00033.
 Transverse strength per square inch, 5,075 lbs. Deflection, .00391.
 Chill, $\frac{1}{16}$ to $\frac{1}{8}$.



No. 1. ANTHRACITE, WITH 10 PER CENT. STEEL.

Tensile strength per square inch, 15,267 pounds. Stretch, .00023.
 Transverse strength per square inch, 5,775 pounds. Deflection, .00270.
 Chill, $\frac{1}{4}$ to $\frac{3}{8}$.



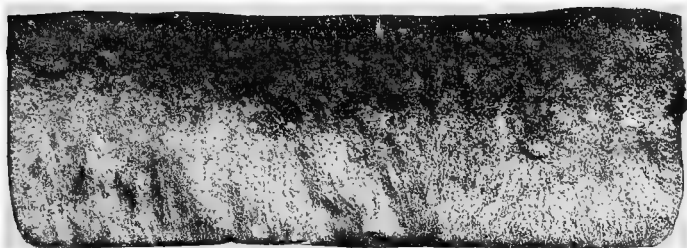
No. 1. ANTHRACITE, WITH 15 PER CENT. STEEL.

Tensile strength per square inch, 17,933 pounds. Stretch, none.
 Transverse strength per square inch, 6,325 pounds. Deflection, .00296.
 Chill, $\frac{5}{8}$.



NO. 1. ANTHRACITE, WITH 20 PER CENT. STEEL.

Tensile strength per square inch, 20,733 pounds. Stretch, .00012.
 Transverse strength per square inch, 6,925 pounds. Deflection, .00254.
 Chill, $\frac{3}{4}$.



CHARCOAL IRON 85 PER CENT. ANTHRACITE IRON $7\frac{1}{2}$ PER CENT.
 STEEL $7\frac{1}{2}$ PER CENT.

Tensile strength per square inch, 28,150 pounds. Stretch, .00007.
 Transverse strength per square inch, 9,425 pounds. Deflection, .00247.
 Chill, $\frac{3}{4}$.

DESCRIPTION OF ALTOONA WHEEL-FOUNDRY AND PLANT.—The Pennsylvania Railroad Company put in operation, in 1874, the wheel-foundry erected at Altoona, which, to produce the greatest economical results, was fitted with the latest improvements, the more novel of which will be noted.

The building of brick, with iron rafters, and slate roof, is so ventilated as to entirely carry off the smoke and gas. Moulding-floor, 138 feet 10 inches by 71 feet 5 inches; annealing-room, 95 feet by 58 feet 7 inches; 2 Mackenzie No. 8 cupolas; plant capacity of each, 30 tons of metal at a heat.

Blowing-Engines—2 steam-cylinders, 16 inches diameter, by 30-inch stroke; 2 blowing-cylinders, 48 inches diameter, by 30-inch stroke, and 60 revolutions per minute, with 5 to 7 ounces pressure of blast to square inch; 13 hydraulic moulding-cranes.

Hydraulic pitting-crane, for annealing-room, with capacity for moving 400 wheels, weighing 220 tons, per day, by the aid of two men. One hydraulic lift, for charging furnace; one hydraulic wheel-breaking machine.

Reservoirs, of a capacity of twelve tons of metal, to secure melted metal from cupola, hung on trunnions and moved by hydraulic power.

Test-cupola, for testing metals, and steam-baths for tempering clay. The other appliances are similar to those in use in other works, but of a more solid construction.

The foundry is operated by 75 men, viz., 13 wheel-moulders, 1 general moulder, 55 laborers, 1 core-maker, 1 cupola man, 1 foreman, 1 assistant, and 2 clerks.

Wheel-moulding is paid for by the piece; average price paid, 35 cents per wheel; core-making, 8 cents per wheel.

Materials used in a charge of metal of 53,500 pounds for one cupola are as follows:

5,350	pounds	old steel rails, or	.	.	.	10	per cent. of charge.
3,745	"	No. 1 charcoal iron, or	.	.	.	7	" "
10,700	"	No. 3 " " "	.	.	.	20	" "
5,350	"	No. 4 " " "	.	.	.	10	" "
12,305	"	No. 1 anthracite iron, or	.	.	.	23	" "
7,490	"	old wheels, or	.	.	.	14	" "
8,560	"	scrap from foundry, or	.	.	.	16	" "
53,500	"					100	" "

The best quality of Lehigh coal is used, 8200 pounds to a charge, or in a ratio of one pound of coal to six and nine-tenths pounds of iron.

MILEAGE OF WHEELS.—The average mileage of wheels of this mixture under Pullman cars is 69,800 miles; under passenger-cars, with frequent action of the brakes, 46,423 miles, or an average mileage of 57,000 miles; a result not excelled, if equaled, by any cast-iron which is used in this country.

REASONS FOR ADOPTING THE PROCESS.—Having in the foregoing given a brief description of the earliest plant and metals used, with mileage, it is now proposed to give the reasons for adopting the steeled-wheel process.

It will be noticed that in the above mixture of irons there is no white iron used to give low irons a chill, and that there is one iron—No. 1 anthracite—largely used. In other wheel-foundries a more or less per cent. of white iron is used to bring up the chill. It is a well-known fact that white iron has comparatively little or no strength. The introduction of such an article can only deteriorate the strength

of the melting-iron. By the use of steel, a great advantage arises in the avoidance of white iron, as steel is the strongest known composition of chemically pure iron with any combination of foreign substances. The benefits of using steel are:

First. That it brings into use, for the manufacture of car-wheels, non-chilling irons, such as low-grade charcoal (warm-blast) irons, anthracite, coke, and raw coal irons.

Second. That it is a means of using advantageously old steel rails, steel, and wrought-iron scrap, which have low market value.

Third. That, by bringing into use low-grade irons, having a consequently low price, a larger assortment may be used, thereby controlling the market and price of metal to a great extent.

Fourth. That, when the proper mixtures are obtained, a much stronger wheel than the ordinary make of cast-iron wheel will be the result.

Fifth. That the grade of chill can readily be controlled.

Sixth. That a better blending of the gray pig with the white iron will be effected.

In order to arrive at these advantages it is necessary,—

First. To have a highly-carbonized iron, such in proportion of graphite as the No. 1 anthracite used.

Second. That it be of a soft, open-grain nature, uniform in grain and in bulk, as put in the furnace.

Third. In the use of anthracite coke iron, it is preferable to have an iron of a non-chilling character, as then a sufficiency of steel can be used to give the strength.

Having the iron, we must next consider the action of steel upon cast-iron in the cupola, and the conditions necessary to produce the best results. The action of steel upon cast-iron in the cupola is that of reducing the carbon, as steel contains a much less percentage of carbon, having only one-half of one per cent. to two and one-half per cent. (.5 per cent. to $2\frac{1}{2}$ per cent.), cast-iron two and one-half per cent. to five per cent. of carbon ($2\frac{1}{2}$ per cent. to 5 per cent.).

The reduction takes place under the following conditions:

That there is enough melted cast-iron in the hearth or crucible of the furnace to take up the steel; and that it is of sufficiently high temperature to rapidly fuse and carbonize the steel. The steel coming in contact with the melted cast-iron, and enveloped by it, it immediately takes up the carbon and becomes cast-iron. The law of uniformity makes the resulting mixture an average of the two constituents, having a greater or less per cent. of carbon, in accordance with the respective percentages of each used.

The cost of production is cheapened by the process. Independent of making available many brands of charcoal irons, besides those generally known and used for car-wheels, the cost is reduced from the fact that suitable steel can be obtained from ten to fifteen dollars per ton less than the standard car-wheel irons; and anthracite and coke irons from ten to twenty dollars less per ton than car-wheel irons. Thus, in the cost of a car-wheel weighing five hundred and fifty pounds, the use of ten per cent. of steel and twenty-five per cent. of anthracite iron with high grades of charcoal iron, will give a reduction of fourteen per cent., while by the use of steel the lower grades of charcoal irons can be used successfully, and a reduction of fully twenty-five per cent. can be made.

This reduction in cost has been fully proved in the operations of the Altoona Foundry, in making over ninety thousand wheels by this process. The mileage returns at the same time compare favorably, and in most cases exceed the mileage of wheels made entirely of charcoal iron from the most renowned makers. The Pennsylvania Railroad Company thus fully recognize the claims made for the process of economy in first cost, and safety and durability in service.

The wheel-foundry thus described is only a portion of the Altoona Railroad shops, in each branch of which great improvements have been made.

REPORTS ON AWARDS.

GROUP XVIII.

Brooks Locomotive Works, Dunkirk, N. Y., U. S.

1 LOCOMOTIVE ENGINE AND TENDER, 3 FEET GAUGE.

Report.—Commended for good materials, workmanship, and finish.

Porter, Bell, & Co., Pittsburg, Pa., U. S.

2 LOCOMOTIVE ENGINE, 3 FEET GAUGE.

Report.—Commended for good workmanship and adaptation to purposes intended.

Baldwin Locomotive Works, Burnham, Parry, Williams, & Co., Philadelphia, Pa., U. S.

3

ONE (1) PASSENGER LOCOMOTIVE, ONE (1) FREIGHT LOCOMOTIVE, 3 FEET GAUGE; TWO (2) LOCOMOTIVES FOR FREIGHT, "CONSOLIDATION" PATTERN, ONE (1) LOCOMOTIVE FOR FREIGHT, "MOGUL" PATTERN, TWO (2) PASSENGER LOCOMOTIVES, "AMERICAN" PATTERN, 4 FEET 8½ INCH GAUGE; ONE (1) MINE LOCOMOTIVE.

Report.—Commended for variety of design, excellent arrangement of details, superior workmanship, and adaptability to the several purposes intended.

4 **Dickson Manufacturing Co., Scranton, Pa., U. S.**

ONE (1) PASSENGER ENGINE, 4 FEET 8½ INCH GAUGE; ONE (1) PASSENGER ENGINE, ONE (1) MINE ENGINE, 3 FEET GAUGE.

Report.—Commended for first-class workmanship, good design, and general adaptability to purposes intended.

Philadelphia and Reading Railroad Co., Reading, Pa., U. S.

5 LOCOMOTIVE BUILT BY APPRENTICES OF COMPANY.

Report.—Commended for special design, good workmanship, and special adaptability to service requirements.

Rogers Locomotive and Machine Works, Paterson, N. J., U. S.

6 WOOD-BURNING LOCOMOTIVE AND TENDER.

Report.—Commended for good design and finish and adaptability to the purpose intended.

7 **Danforth Locomotive and Machine Co., Paterson, N. J., U. S.**

ONE (1) LOCOMOTIVE ENGINE, 4 FEET 8½ INCH GAUGE; ONE (1) PLANTATION ENGINE, 3 FEET GAUGE.

Report.—Commended for good design, workmanship, and excellent finish.

Kristinehamn Machine Manufacturing Co., by Harald Asplund, Kristinehamn, Sweden.

8

LOCOMOTIVE ENGINE.

Report.—Commended for good workmanship.

Mason Machine Works, Taunton, Mass., U. S.

9

LOCOMOTIVE ENGINE, 3 FEET GAUGE.

Report.—Commended for good materials and workmanship, and adaptation to purposes intended.

J. B. Fondu, Brussels, Belgium.

10

LOCK FOR RAILWAY CARRIAGES.

Report.—Commended for adaptability for special purposes.

New York Central & Hudson River Railroad Co., U. S.

11

POSTAL CAR.

Report.—Commended for good workmanship and convenient arrangement for purposes intended.

Pennsylvania Railroad Co., Altoona, Pa., U. S.

12

UNITED STATES POSTAL CAR.

Report.—Commended for suitability to the object for which it is designed

William G. Creamer & Co., New York City, N. Y., U. S.

13

CAR FITTINGS, TRIMMINGS, AND FIXTURES.

Report.—Commended for good designs and excellence of workmanship.

Baker, Smith, & Co., New York, N. Y., U. S.

14

RAILWAY CAR HEATER.

Report.—Commended for novelty of arrangement and adaptability to purposes intended.

15

Post & Co., Cincinnati, Ohio, U. S.

CAR FITTINGS, TRIMMINGS, AND FIXTURES, AND LOCOMOTIVE HEAD LAMPS.

Report.—Commended for tasteful designs and excellence of workmanship.

16

Pullman Palace Car Co., Chicago, Ill., U. S.

ONE (1) PULLMAN HOTEL AND SLEEPING CAR; ONE (1) PULLMAN PARLOR CAR.

Report.—Commended for excellent designs, convenience of arrangement, and superior workmanship and finish.

17

Jackson & Sharp Co., Wilmington, Del., U. S.

FIRST-CLASS PASSENGER CAR, GAUGE 4 FEET 8½ INCHES; BOUDOIR AND LIBRARY CAR, GAUGE 3 FEET.

Report.—Commended for good workmanship, finish, and convenience of arrangement.

Wason Manufacturing Co., Springfield, Mass., U. S.

18

PASSENGER CAR.

Report.—Commended for substantial construction and good workmanship.**The Westinghouse Air Brake Co., Pittsburg, Pa., U. S.**

19

WESTINGHOUSE AUTOMATIC AIR BRAKE.

Report.—Commended for safety, efficiency, durability, and adaptability to the purposes intended.**Paul Klunzinger, Vienna, Austria.**

20

SELF-ACTING COUPLINGS, BRAKES, AND BUFFERS.

Report.—Commended for special adaptability for mining operations on railways with steep gradients.**Glöckner Brothers, Tschirndorf, Silesia, Germany.**

21

BLOCKS FOR CAR BRAKES.

Report.—Commended for good workmanship and adaptability of the material to the purpose intended.

22

Lobdell Car Wheel Co., Wilmington, Del., U. S.

CHILLED CAST IRON WHEELS FOR TRAMWAYS, AND FOR RAILWAY CARS AND LOCOMOTIVES; PAIR OF TURNED CHILLED WHEELS.

Report.—Ist. As to chilled cast iron wheels.—Commended for the excellence of material, process of manufacture, and durability. 2d. As to the turned chilled wheels.—Commended for the originality and the increased wear of the wheels.**Union Car Spring Manufacturing Co. of New Jersey, New York, N. Y., U. S.**

23

CAR SPRINGS, SPIRAL AND VOLUTE.

Report.—Commended for excellent material and good workmanship.**Hamilton Steeled Wheel Co., Philadelphia, Pa., U. S.**

24

CHILLED CAR WHEELS.

Report.—Commended for excellence of process, economy of production, and durability.**Davenport, Fairbairn, & Co., Erie, Pa., U. S.**

25

CHILLED CAST IRON WHEELS.

Report.—Commended for good materials, good workmanship, and durability.

26

Nichols, Pickering, & Co., Philadelphia, Pa., U. S.

STEEL SPRINGS, ELLIPTIC, SPIRAL, AND VOLUTE, FOR RAILWAY CARS AND LOCOMOTIVES.

Report.—Commended for good workmanship and great variety of forms.**McKee & Fuller, Catasauqua, Lehigh County, Pa., U. S.**

27

RAILROAD AND MINE CAR WHEELS.

Report.—Commended for good workmanship and material.

The Washburn Car Wheel Co., Hartford, Conn., U. S.

28 STEEL-TIRED CAR WHEELS (SAX & KEAR'S PATENT).

Report.—Commended for simplicity of construction, good workmanship and materials, and proved safety and durability.

29 **Cayuta Wheel & Foundry Co., Waverly, N. Y., U. S.**

CHILLED WHEELS FOR ENGINE, TENDER, PASSENGER, FREIGHT, COAL, AND MINE CARS;
STREET CAR WHEELS.

Report.—Commended for good materials and workmanship.

Barnum Richardson Co., Salisbury, Conn., U. S.

30 CAST CHILLED CAR WHEELS.

Report.—Commended for the excellence of the material and workmanship, and special adaptation to the construction of chilled wheels.

Baltimore Car Wheel Co., Baltimore, Md., U. S.

31 CHILLED CAST IRON CAR WHEELS AND ENGINE TIRES.

Report.—Commended for good materials and excellent workmanship.

Culmer Spring Co., Pittsburg, Pa., U. S.

32 SPIRAL SPRINGS FOR RAILWAY CARS.

Report.—Commended for good designs, workmanship, and material.

33 **A. French & Co., Pittsburg, Pa., U. S.**

RAILWAY ELLIPTIC SPRINGS FOR PASSENGER AND FREIGHT CARS AND LOCOMOTIVES.

Report.—Commended for good design, excellence of workmanship and material, uniformity of action, and durability.

34 **N. & A. Middleton & Co., Philadelphia, Pa., U. S.**

GODLEY'S IMPROVED SPIRAL SPRINGS AND COMBINED SPIRAL CAR SPRINGS.

Report.—Commended for good combination of spiral springs, and good workmanship.

Ramapo Wheel & Foundry Co., Ramapo, Rockland County, N. Y., U. S.

35 CHILLED CAST IRON WHEELS.

Report.—Commended for excellence of material and process of manufacture, and resulting durability.

American Paper Car Wheel Co., Hudson, Columbia County, N. Y., U. S.

36 WHEELS OF COMPRESSED PAPER, ROUND METAL HUB, STEEL TIRES.

Report.—Commended for novelty of design and successful combination of the materials.

A. Whitney & Sons, Philadelphia, Pa., U. S.

37 CHILLED CAST IRON WHEELS.

Report.—Commended for excellence of material and process of manufacture, and resulting durability.

Samuel Louis Harrison, San Francisco, Cal., U. S.

38 RAILROAD AXLE WITH INDEPENDENT WHEELS, FOR STREET CARS.

Report.—Commended for adaptability to street railway cars.**Carl Ekman, Finspong, Sweden.**

39 CHILLED CAST IRON RAILWAY WHEELS.

Report.—Commended for goodness of work and economy of production.**Surahammar Iron Works, Carl Alexanderson, Surahammar, Sweden.**

40 RAILWAY WHEELS AND AXLES.

Report.—Commended for the goodness of the work, and the proven durability of the articles exhibited.**Fagersta Iron & Steel Works, Fagersta, Westanfors, Sweden.**

41 AXLES AND SPRINGS.

Report.—Commended for adaptability of material to railway axles, springs, and tires.**Toronto Car Wheel Co., Toronto, Canada.**

42 CAR WHEELS OF CHILLED IRON.

Report.—Commended for successful application of the material.**McDougall & Co., Montreal, Canada.**

43 CHILLED IRON CAR WHEELS.

Report.—Commended for excellence of material and workmanship.**Obookhof Steel Foundry, near St. Petersburg, Russia.**

44 RAILWAY WHEELS, TIRES, AND AXLES.

Report.—Commended for good material and workmanship.**Sandvikens Iron Works, Gefle, Sweden.**

45 RAILWAY WHEELS AND AXLES.

Report.—Commended for the excellence of the material and workmanship.**Anonymous Society of the Factories of La Dyle, Louvain, Belgium.**

46 CAR WHEELS.

Report.—Commended for good workmanship and strength.**Anonymous Society of Rolling Mills, High Furnaces, Forges, Foundries, and Factories of La Providence, Marchienne au Pont, near Charleroi (Hainaut), Belgium.**

47 WROUGHT IRON RAILWAY WHEELS.

Report.—Commended for the solidity resulting from the system of construction.**Brunon Brothers, Rive de Gier, France.**

48 WHEELS FORGED BY HYDRAULIC PRESSURE.

Report.—Commended for good material and workmanship.

Lucien Arbel, Rive de Gier, France.

49

FORGED IRON WHEELS.

Report.—Commended for good workmanship and economy.**Valère Mabilie, Mariemont, Hainaut, Belgium.**

50 WROUGHT IRON BUFFERS WITH VOLUTE SPRINGS, AND COUPLINGS.

Report.—Commended for excellence of workmanship and economy of production.**Frederick Krupp, Essen, Germany.**

51

WHEELS, AXLES, TIRES, RAILS, SPRINGS, AND FROGS.

Report.—Commended for superior materials and workmanship.

52 Camozzi & Schlösser, Frankfort-on-the-Main, Germany.

SELF-ACTING INSTRUMENT FOR VERIFYING THE GAUGE AND MEASURING THE RELATIVE LEVELS OF THE RAILS.

Report.—Commended for suitability for the object for which it is designed.**A. de Maré, Ankarsrum Iron Works, Ankarsrum, Sweden.**

53

RAILWAY CROSSING OF CHILLED CAST IRON.

Report.—Commended for the special adaptability of the metal to railway crossings.

54

Wm. Wharton, Jr., Philadelphia, Pa., U. S.

BESSEMER STEEL-GROOVED RAILS FOR STREET RAILWAY CURVES; TURN-TABLE, CAST IRON FROGS, SWITCHES, AND CROSSINGS FOR STREET RAILWAYS.

Report.—Commended for suitability to the object for which the exhibits have been designed.**The Wharton Railroad Switch Co., Philadelphia, Pa., U. S.**

55

RAILROAD SAFETY SWITCH WITH UNBROKEN MAIN TRACK.

Report.—Commended for novelty of design for maintaining an unbroken main track, safety and efficiency.**Pennsylvania Steel Co., Philadelphia, Pa., U. S.**

56.

RAILWAY SWITCHES.

Report.—Commended for good workmanship, and suitability for trailing points.**Pennsylvania Railroad Co., Altoona, Pa., U. S.**

57

RAILROAD TRACK.

Report.—Commended for excellence of system, solidity, and goodness of workmanship.**The Rosseau Railway Signal Co., New York, N. Y., U. S.**

58

ELECTRIC RAILWAY SIGNAL.

Report.—Commended for security of running trains, resulting from the good dispositions of the signal apparatus.

59 **Saxby & Farmer, Kilburn, London, England.**

RAILWAY SIGNALS, SWITCHES, AND LEVEL CROSSING GATES; LOCKING AND INTERLOCKING OF SIGNALS AND SWITCHES, AND LOCKING POINTS.

Report.—Commended for originality, ingenious and effective arrangement of parts, and adaptability to purposes intended.

60 **Brierley, Sons, & Reynolds, London, England.**

RAILWAY SIGNALS AND SWITCHES; LOCKING AND INTERLOCKING OF SIGNALS AND SWITCHES, AND LOCKING THE POINTS.

Report.—Commended for adaptability to purposes intended; improvement in locking the switch-points.

61 **Emil Tilp, Vienna, Austria.**

CONNECTION BETWEEN LOCOMOTIVE AND TENDER FOR REDUCING LATERAL MOTION.

Report.—Commended for adaptability to purpose intended.

S. G. Reed, Boston, Mass., U. S.62 **APPARATUS FOR HEATING LOCOMOTIVE TIRES WITH GAS.**

Report.—Commended for facility in application and simplicity of design.

J. G. Brill & Co., Philadelphia, Pa., U. S.63 **STREET CAR FOR TWO (2) HORSES.**

Report.—Commended for good workmanship, high finish, and lightness of draught.

64 **John Stephenson & Co. (Limited), New York, N. Y., U. S.**

STREET TRAMWAY CAR FOR TWO (2) HORSES; STREET TRAMWAY CAR FOR ONE (1) HORSE.

Report.—Commended for superior finish and workmanship.

J. M. Jones & Co., West Troy, N. Y., U. S.65 **STREET CAR FOR TWO (2) HORSES.**

Report.—Commended for good workmanship and lightness of draught.

Aveling & Porter, Rochester, Kent, England.66 **TRACTION ENGINE.**

Report.—Commended for novelty of design; good workmanship; adaptability to purpose intended.

SIGNING JUDGES OF GROUP XVIII.

The numbers annexed to the names of the Judges indicate the reports written by them respectively.

DOUGLAS GALTON, 10, 11, 12, 13, 14, 15, 16, 17, 18, 54, 63, 64, 65, 66.

FELICIAN SLATAPER, 19, 20, 50, 52, 53, 55, 56.

T. A. MORRIS, 1, 2, 3, 4, 5, 6, 7, 8, 9, 61.

R. E. RICKER, 59, 60.

ERNST PONTZEN, 22, 24, 25, 27, 28, 29, 30, 31, 35, 36, 37, 39, 40, 42, 43, 44, 46, 47, 48, 49, 57, 62.

E. SCHAAAR, 21, 23, 26, 32, 33, 34, 38, 41, 45, 51, 58.

SUPPLEMENT TO GROUP XVIII.

REPORTS

OF

JUDGES ON APPEALS.

JUDGES.

JOHN FRITZ, Bethlehem, Pa.
 EDWARD CONLEY, Cincinnati, Ohio.
 CHARLES STAPLES, Jr., Portland, Me.
 BENJ. F. BRITTON, New York City.
 H. H. SMITH, Philadelphia, Pa.

COLEMAN SELLERS, Philadelphia, Pa.
 JAMES L. CLAGHORN, Philadelphia, Pa.
 HENRY K. OLIVER, Salem, Mass.
 M. WILKINS, Harrisburg, Oregon.
 S. F. BAIRD, Washington, D. C.

National Car Spring Co., New York, N. Y., U. S.

1. STEEL AND RUBBER CAR SPRINGS.

Report.—Commended for excellence in manufacture and fitness for purposes intended.

Towle Manufacturing Co., New York, N. Y., U. S.

2 BELL PUNCHES AND FARE REGISTERS.

Report.—Commended for good workmanship and protection against fraud.

Arboga Foundry and Iron Works, Arboga, Sweden.

3 RAILWAY WHEELS, TIRES, AND AXLES.

Report.—Railway wheels of chilled cast iron, shown in place on axles and by broken specimens, to display the depth of chill and grade of iron. Commended for good quality and good chilling property of iron used.

The Railway Safety Gate Co., Gen. Lysander Flagg, Agent, Pawtucket, R. I., U. S.

4 RAILWAY SAFETY GATE.

Report.—Commended for convenience, utility, and adaptation for its intended purpose, and for ease of manipulation.

SIGNING JUDGES OF SUPPLEMENT TO GROUP XVIII.

The figures annexed to the names of the Judges indicate the reports written by them respectively.

CHARLES STAPLES, 1, 2.
 COLEMAN SELLERS, 3, 4.

United States Centennial Commission.

INTERNATIONAL EXHIBITION,
1876.

REPORTS AND AWARDS

GROUP XIX.

EDITED BY
FRANCIS A. WALKER,
CHIEF OF THE BUREAU OF AWARDS.

PHILADELPHIA:
J. B. LIPPINCOTT & CO.
1877.

Entered, according to Act of Congress, in the year 1876, by the
CENTENNIAL BOARD OF FINANCE,
In the Office of the Librarian of Congress at Washington.

SYSTEM OF AWARDS

[*Extract from Circular of April 8, 1876.*]

Awards shall be based upon written reports attested by the signatures of their authors.

The Judges will be selected for their known qualifications and character, and will be experts in departments to which they will be respectively assigned. The foreign members of this body will be appointed by the Commission of each country and in conformity with the distribution and allotment to each, which will be hereafter announced. The Judges from the United States will be appointed by the Centennial Commission.

* * * * *

Reports and awards shall be based upon inherent and comparative merit. The elements of merit shall be held to include considerations relating to originality, invention, discovery, utility, quality, skill, workmanship, fitness for the purposes intended, adaptation to public wants, economy and cost.

Each report will be delivered to the Centennial Commission as soon as completed, for final award and publication.

Awards will be finally decreed by the United States Centennial Commission, in compliance with the Act of Congress, and will consist of a diploma with a uniform Bronze Medal, and a special report of the Judges on the subject of the Award.

Each exhibitor will have the right to produce and publish the report awarded to him, but the United States Centennial Commission reserves the right to publish and dispose of all reports in the manner it thinks best for public information, and also to embody and distribute the reports as records of the Exhibition.

ORGANIZATION AND DUTIES OF THE JUDGES.

[*Extract from Circular of May 1, 1876.*]

Two hundred and fifty Judges have been appointed to make such reports, one-half of whom are foreigners and one-half citizens of the United States. They have been selected for their known qualifications and character, and are presumed to be experts in the Groups to which they have been respectively assigned. The foreign members of this body have been appointed

by the Commission of each country, in conformity with the distribution and allotment to each, adopted by the United States Centennial Commission. The Judges from the United States have been appointed by the Centennial Commission.

To facilitate the examination by the Judges of the articles exhibited, they have been classified in Groups. To each of these Groups a competent number of Judges (Foreign and American) has been assigned by the United States Centennial Commission. Besides these, certain objects in the Departments of Agriculture and Horticulture, which will form temporary exhibitions, have been arranged in special Groups, and Judges will be assigned to them hereafter.

The Judges will meet for organization on May 24, at 12 M., at the Judges' Pavilion. They will enter upon the work of examination with as little delay as practicable, and will recommend awards without regard to the nationality of the exhibitor.

The Judges assigned to each Group will choose from among themselves a Chairman and a Secretary. They must keep regular minutes of their proceedings. Reports recommending awards shall be made and signed by a Judge in each Group, stating the grounds of the proposed award, and such reports shall be accepted, and the acceptance signed, by a majority of the Judges in such Group.

The reports of the Judges recommending awards based on the standards of merit referred to in the foregoing System of Awards, must be returned to the Chief of the Bureau of Awards not later than July 31, to be transmitted by him to the Centennial Commission.

Awards will be finally decreed by the United States Centennial Commission, in compliance with the Act of Congress of June 1, 1872, and will consist of a special report of the Judges on the subject of the Award, together with a Diploma and a uniform Bronze Medal.

Upon matters not submitted for competitive trial, and upon such others as may be named by the Commission, the Judges will prepare reports showing the progress made during the past hundred years.

Vacancies in the corps of Judges will be filled by the authority which made the original appointment.

No exhibitor can be a Judge in the Group in which he exhibits.

An exhibitor, who is not the manufacturer or producer of the article exhibited, shall not be entitled to an award.

The Chief of the Bureau of Awards will be the representative of the United States Centennial Commission in its relations to the Judges. Upon request, he will decide all questions which may arise during their proceedings in regard to the interpretation and application of the rules adopted by the Commission relating to awards, subject to an appeal to the Commission.

A. T. GOSHORN,
Director-General.

[*Extract from Director-General's Address to Judges, May 24, 1876.*]

“The method of initiating awards which we have adopted differs in some respects from that pursued in previous exhibitions. In place of the anonymous verdict of a jury, we have substituted the written opinion of a Judge. On this basis awards will carry the weight and guarantees due to individual personal character, ability, and attainments, and to this extent their reliability and value will be increased. It is not expected that you will shower awards indiscriminately upon the products in this vast collection. You may possibly find a large proportion in no way raised above the dead level, nor deserving of particular notice. The standard above which particular merit worthy of distinction begins is for you to determine. In this regard I have only to express the desire of the Centennial Commission, that you should do this with absolute freedom, and when you meet with a product which you consider worthy of an award, we desire you to say, in as few words as you may deem suitable, why you think so.

“This, gentlemen, is all we ask of you in the Departments of Awards. Opinions thus expressed will indicate the inherent and comparative merits, qualities, and adaptations of the products,—information which the public most desires.

“Elaborate general reports and voluminous essays, though of great value as sources of general information, give little aid in determining the reliable or intrinsic merits of particular, individual products.

“The regulations which have been published divide the work of awards into three parts:

“1st. The individual work of the Judges.

“2d. The collective work of the groups of Judges.

“3d. The final decisions of the United States Centennial Commission in conformity with the acts of Congress.

“Each award will thus pass three ordeals, which, doubtless, will be ample and satisfactory.”

GROUP XIX.

JUDGES.

AMERICAN.

ISAAC NEWTON, New York City.
J. W. GRIFFITHS, New York City.
H. C. GOODSPEED, Salt Lake City, Utah.

FOREIGN.

F. H. RICH, R.E., Great Britain.

The following named Judge was temporarily assigned from Group XVI. to assist in the examination of the classes attached to his name :

LUIZ DE SALDANHA DA GAMA.—Sailing vessels used in commerce, in war, and for pleasure ; and rowing boats of all kinds. Steam capstans, windlass, deck-winches, and steering apparatus. Ropes and cordage. Screw propellers ; wheels for the propulsion of vessels, etc.

GROUP XIX.

VESSELS AND APPARATUS OF TRANSPORTATION, NOT INCLUDED IN OTHER GROUPS.

CLASS 590.—Suspended-cable railways.

CLASS 591.—Transporting cables.

CLASS 592.—Balloons, and apparatus, etc.

CLASS 593.—See Group XX.

CLASS 594.—Boats and sailing vessels. Sailing vessels used in commerce. Sailing vessels used in war. Yachts and pleasure boats. Rowing boats of all kinds.

Life boats and salvage apparatus, with life-rafts, belts, etc. Submarine armor, diving bells, etc. Ice boats.

CLASS 595.—Steamships, steamboats, and all vessels propelled by steam.

CLASS 554.—Screw propellers; wheels for the propulsion of vessels, etc.

CLASS 596.—Vessels for carrying telegraph cables and railway trains; also coal barges, water boats, and dredging-machines; screw and floating docks; and for other special purposes.

CLASS 597.—Steam capstans, windlass, deck-winches, and steering apparatus.

CLASS 287.—Ropes, cordage.

GENERAL REPORT

OF THE

JUDGES OF GROUP XIX.

INTERNATIONAL EXHIBITION,
Philadelphia, 1876.

PROF. F. A. WALKER, *Chief of Bureau of Awards:*

SIR,—In accordance with your request, I have the honor to submit a report on the exhibits that appear to me to deserve special notice in Group XIX., of which section I was one of the Judges and Chairman.

I have the honor to be, sir, your obedient servant,

F. H. RICH, *Col. R. E.,*
Chairman of Group XIX.

GROUP XIX.

VESSELS AND APPARATUS OF TRANSPORTATION.

The exhibition in this section of engineering was not large. I take the subjects in the class order in which they are grouped in the official list.

There were 158 exhibits in Group XIX. submitted to the Judges. Of these 7 were in Class 596, which comprised vessels for carrying telegraph-cables and railway-trains, coal-barges, water-boats, and dredging-machines, screw- and floating-docks, and vessels for other special purposes. In Class 594 there were 62 exhibits, which comprised boats and sailing-vessels used in commerce, sailing-vessels used in war, yachts and pleasure-boats, and rowing-boats of all kinds. In Class 595, which comprised steamships, steamboats, and all vessels propelled by steam, there were 15 exhibits. Class 554, which comprised screw-propellers, wheels for the propulsion of vessels, etc., was represented by 12 exhibits. In Class 597, which comprised steam-capstans, windlasses, deck-winches, and steering apparatus, there were 16 exhibits. In Class 287, which comprised ropes and cordage, there were 46 exhibits. There were no exhibits submitted in Classes 590, suspended cable-railways; 591, transporting cables; and 592, balloons, etc.

CLASS 596.—VESSELS FOR SPECIAL PURPOSES.

The dredging-machines of the American Dredging-Machine Company consisted of a large iron bucket fixed at the end of a beam, which is managed and worked by steam machinery. These machines are simple and moderately cheap, but they are only suitable for working in smooth water. They are particularly well adapted for dredging out docks, or lay-bies for vessels on the banks of rivers, as the machines are very efficient in clearing out corners.

There were several models of floating-docks, among which was the Bermuda floating-dock.

The models of a gridiron floating-dock, and staging for dry-dock,

ing vessels, which were exhibited by Messrs. Clark & Standfield, of London, deserve particular mention on account of the novelty and simplicity of construction and the comparative small cost at which a large number of vessels could be dry-docked. The one floating-dock can be used for placing as many vessels on the staging as the staging is constructed to hold.

CLASS 594.—SAILING-VESSELS.

The exhibits in this class consisted of models of vessels, executed with more or less care and accuracy of detail, but in the greater number of cases no data on which to form an opinion of their relative merits were furnished. Among them the models and worked-out drawings of Mr. Arenty, of Norway, appeared to be the only ones in a complete state, and deserving of special notice.

The paper boats exhibited by Messrs. Waters & Sons, of Troy, New York, were a novelty. They were made of coarse paper, put together with shellac, very strong in proportion to their weight, and are likely to be useful for shooting-punts, traveling-canoes, and racing-gigs. These boats are very easily repaired. The paper of which they are made is of two kinds: one made from Manila grass, and the other from Russia duck. It is rolled in sheets eighty inches wide, and of any length required.

The rowing apparatus of Mr. Lyman, of Hamburg, New York, called "bow-facing rowing machinery," is a new invention, and deserving of notice, as likely to be useful for shooting-punts, and all pleasure-boats used by only one person. The oar is cranked, or made in three pieces with two hinge-joints near the rowlock, so that the oarsman, by the same motion of his arms as in ordinary rowing, pulls the boat in the direction that he is facing, instead of backwards as with common oars.

CLASS 595.—STEAMSHIPS.

The exhibits in this class consisted of a large number of models. The model of the ship "Frisia," exhibited by the Hamburg Steamship Company, was a very nice piece of work, and the details appeared to be most accurately carried out.

CLASS 554.—SCREW-PROPELLERS, WHEELS, ETC.

Two full-sized steam-launches or yachts were exhibited in this class. They were open boats for river use, and were well built; one of them was reported to steam twenty miles an hour in smooth water, but

there was no opportunity of testing this, as these boats were placed in Machinery Hall.

Major Mallory, of Bridgeport, Connecticut, exhibited a screw steam-yacht in which the screw not only propelled the vessel, but also acted as a rudder. The screw could be moved to either side, in a half-circle, as the screw-shaft was pivoted near the stern. The yacht was afloat in the Delaware River. It could be turned round (the whole circle) by means of the screw, in a little more than its own length, in one minute and forty-five seconds. This invention may probably be usefully applied to dock-yard launches for intricate river navigation, as the screw forms a most powerful and effective rudder. The length of the yacht was ninety-five feet over all, and the length of keel was eighty-four feet.

The life-raft exhibited by the Monitor Life-Saving Raft Company, of New York, consisted of india-rubber bags inclosed in two strong canvas bags, of the circular tube form, with conical ends. The raft was buoyant, strong, simple in all its parts, and easily put together. It showed good floating properties, and was manageable when placed in the water. It appeared to be a very portable and serviceable machine, well calculated for saving life in cases of emergency, or for pontooning purposes.

The ice-boat or ice-yacht exhibited by Mr. Irving Grinnell, of New Hamburg, New York, is deserving of commendation. It is rigged like a cutter, runs on three skates, and is reported to attain a speed of sixty miles an hour when running with a favorable side wind. This very speedy mode of traveling over the ice must be attended with considerable risk.

CLASS 597.—STEAM-CAPSTANS, WINDLASSES, ETC.

The exhibits in Class 597 which appeared to be most worthy of notice were as follows: The steam steering apparatus by Mr. Siccles; the capstans, windlasses, and chain-stoppers exhibited by Messrs. Coffin & Woodward, of Boston, Massachusetts, which were simple and effective; the windlass of the American Ship-Windlass Company, of Providence, Rhode Island, in which a tongue, actuated by a cam, is substituted for the ordinary pawl and rack; the chain cables of Messrs. Prodi, of France, which were made without any welds; and the workmanship and material in the chain cables of Messrs. Bradlee & Co., of Philadelphia, appeared to be excellent.

CLASS 287.—ROPES, CORDAGE.

The exhibits of ropes and cordage were very numerous and very

good. Great excellence was apparent in the exhibits of Messrs. Sewell & Day, of Boston, Massachusetts, and the other American manufacturers of these articles. Russia, Italy, and Brazil had numerous exhibits. The Brazilian flax appeared to be very good, but the rope manufactured in that country is rough.

The Brazilian and Russian Governments exhibited numerous models of their ships of war and of their military and dock-yard works.

One building of considerable size was completely taken up with the exhibits of the United States Government works, among which the model of the mining works at Hell Gate for deepening the channel leading to Long Island Sound was most interesting and instructive. Samples of the material used in the United States Government works, and samples of all the animal, vegetable, and mineral products of the country, which were collected in this building, formed a most comprehensive and interesting exhibit of the wealth, industry, and progress of the United States.

ROPES AND CORDAGE.

BY HENRY A. GOODSPEED.

This exhibit comprised ropes and cordage made from hemp, iron, and steel wire.

The countries represented were Russia, Norway, Sweden, Austria, the Netherlands, Hungary, Belgium, Spain, England, Brazil, Chili, New Zealand, Australia, and the United States.

ENGLAND.

From England proper there was only a single exhibit, consisting of three bales of machine-spun oakum of superior quality.

NEW ZEALAND.

A fine display, from a number of exhibitors, of ropes and cordage of various sizes, made from Manila and native hems. The native hemp is called Phormium, and, as it appeared in the manufactured rope, is a poor material for the purposes of rope for ships' use. The fibre seemed to have been injured in its preparation, and the hatcheling very poorly done. Almost all were poorly prepared, and had been injured by dust and exposure.

AUSTRALIA.

This exhibit consisted of ropes and lines made from European, Manila, and coir hems, in no respect worthy of special mention.

NOVA SCOTIA.

This exhibit consisted of a great variety of large and small ropes of tarred and untarred Russia and Manila hems and oakum. Much of the rigging seemed to have been made for a long time, or it might possibly have been damaged in transportation. It was, however, unworthy of special mention.

AUSTRIA.

This country made only one exhibit, of small sample specimens of small ropes and twines, coarsely made from very good material.

HUNGARY.

Hemp and wire ropes were exhibited in considerable variety, but in very small quantities. The hemp ropes were principally made from Russia hemp; the wire ropes were in different forms, all of fair quality.

BELGIUM.

A single exhibit, of sample specimens of small ropes made from good material, and of quite good manufacture.

NETHERLANDS COLONIES.

The Netherlands Colonies exhibited small quantities of small, hawser-laid hemp ropes of inferior make.

SWEDEN.

Only a single exhibit was contributed, which was of iron-wire rope of various sizes, and of fair quality.

NORWAY.

There was only one exhibit, consisting of six coils of Russia hemp rope, the material being good, and the manufacture better than ordinary.

BRAZIL.

The Government was the only exhibitor from Brazil, and its exhibit was not very extensive nor complete. It consisted of small quantities of small-sized ropes, halyards, deep-sea-lines, log-lines, marline, flag-lines, sash-cord, fish-lines, lead-lines, and hide tiller-rope. With the exception of the hide rope, all were made from Brazilian hemp. The manufacture was not the best, but the hemp was of fine quality, and was next to Italian and Russian in fineness and strength.

CHILI.

There were two exhibits of a variety of small specimen samples of rope, made from Manila and native hems and iron wire. The material was all of good quality, but the manufacture was rough and uneven.

SPAIN.

Represented by a small exhibit, from Barcelona, of small specimens of tarred and untarred ropes and rigging, made from ordinary material, and of ordinary manufacture.

RUSSIA.

This Government exhibited seven coils of galvanized-iron-wire rope of various sizes, two coils of tarred and two of untarred hemp rope, and four short pieces of large-sized hawsers. The wire rope was of ordinary quality; the hemp ropes were made from very fine material, and one of the pieces of hawser, laid up with six strands and a core, was a superb specimen of manufacture, worthy of special mention. The other exhibit from this country consisted of three coils of coarse yarns and small rope, made from excellent material, for agricultural purposes.

UNITED STATES.

This country was much the largest contributor in this class. It was apparent that a great and commendable rivalry among the manufacturers to excel in making a superior article resulted in the production of finer ropes, cordage, lines, and twines than were ever before exhibited. In every instance the exhibitors, including the United States Government, were worthy of especial mention, and it was a matter of serious regret that we could not in some way express our appreciation of the great effort made by these contributors to enhance the attractions of the Exhibition.

The iron and steel wire ropes were of superior quality, and were exhibited in a most excellent manner. The oakum was of fine quality, though only moderate in quantity and number of exhibitors. The twines made from American hemp and flax were of most excellent quality, and superior in evenness and finish.

It was something of a disappointment to find that the English manufacturers of ropes and cordage were not at all represented.

The class, taken as a whole, was satisfactory.

REPORTS ON AWARDS.

GROUP XIX.

1. F. W. Page, New York, N. Y., U. S.

OARS.

Report.—Commended for good material, good shape, and good workmanship.

2. Marcus Ormsbee, Brooklyn, N. Y., U. S.

LIFE-SAVING SUIT.

Report.—Commended as new, simple, and effective.

3. H. Arentz, Christiania, Norway.

MODELS AND DRAWINGS OF VESSELS.

Report.—Commended for excellence of models and plans of commercial vessels.

4. J. Brandt, Christiania, Norway.

MODELS AND DRAWINGS OF VESSELS.

Report.—Commended for excellence of models and drawings of ship, bark, and pilot boat.

5. D. Herald, Gore's Landing, Ontario, Canada.

HUNTING CANOES.

Report.—Commended for novelty of constructing without frames in the patent canoe, and for lightness, strength, and good workmanship of the ordinary hunting canoe.

6. The Rider Life-Raft Co., New York, N. Y., U. S.

TWO (2) LIFE RAFTS.

Report.—Commended for lightness, buoyancy, and efficiency as a life-saving apparatus on the beach or elsewhere.

7. William English, Peterborough, Ontario, Canada.

HUNTING CANOE.

Report.—Commended for strength, lightness, and good workmanship.

8. C. & R. Poillon, New York, N. Y., U. S.

MODEL OF SCHOONER YACHT "SAPPHO."

Report.—Commended as being the model of the fastest-sailing yacht known, as shown by records.

9. **E. Waters & Sons, Troy, N. Y., U. S.**

PAPER BOATS.

Report.—Commended for new material used in boat-building, strength and stiffness, facility for repairing, and moderate cost.

10. **R. T. Dodge, Boston, Mass., U. S.**

OARS.

Report.—Commended for good shape, good workmanship, and good material.

11. **William Lyman, Middlefield, Conn., U. S.**

PATENT BOW-FACING ROWING-GEAR.

Report.—Commended for the advantage obtained for special service of pulling the boat in the direction in which the rower is facing.

12. **Irving Grinnell, New Hamburg, N. Y., U. S.**

ICE YACHT.

Report.—Commended for good proportion, good material, and good workmanship.

13. **Life-Saving Raft Co., New York, N. Y., U. S.**

MONITOR LIFE-SAVING RAFT.

Report.—Commended for simplicity, efficiency, lightness, and facility for bringing into use in time of need.

14. **New York Safety Steam-Power Co., New York, N. Y., U. S.**

STEAM YACHT.

Report.—Commended for fitness for general purposes.

15. **Doughty & Kappella, Philadelphia, Pa., U. S.**

STEAM YACHT.

Report.—Commended for fitness for general purposes.

16. **Trajano A. de Carvalho, Rio de Janeiro, Brazil.**

MODELS OF TWO (2) CORVETTES AND ONE (1) STEAM LAUNCH.

Report.—Commended for new lines of vessels applicable to war and merchant ships, as shown by trials made both in Brazil and England and applied to vessels already built.

17. **The William Cramp & Sons Ship and Engine Building Co., Philadelphia, Pa., U. S.**

STEAMSHIP MODELS.

Report.—Commended for steamship models and elements of stability shown in the calculations and records of Atlantic steamers furnished.

18. **Motala Iron and Steel Works, Motala, Sweden.**

STEEL STEAM-PROPELLER BOAT.

Report.—Commended for excellence of material and superior workmanship, being the representative of a class of boats used around Stockholm, Sweden, and adjacent waters.

19. John Englis & Son, Brooklyn, N. Y., U. S.

MODELS AND CALCULATIONS OF STEAMSHIPS "CITY OF NEW YORK" AND "CITY OF VERA CRUZ."

Report.—Models of successful steamships, as shown by records.

20. Jno. B. Roach, Chester, Pa., U. S.

MODELS OF STEAMSHIPS.

Report.—Models of successful steamships, as shown by records.

21. Hamburg-American Steam Packet Co., Hamburg, Germany.

MINIATURE MODEL OF HAMBURG-AMERICAN PACKET SHIP "FRISIA."

Report.—A well-finished piece of work; pretty miniature representation of the interior fittings of the vessel.

22. Frank G. Fowler, Bridgeport, Conn., U. S.

STEAM-STEERING PROPELLER.

Report.—It is well adapted to light-draught vessels, steering without a rudder, and working readily in all directions.

23. William H. Mallory, Bridgeport, Conn., U. S.

STEERING SCREW PROPELLER.

Report.—Commended for a device applied to the screw propeller, whereby the vessel may be steered without a rudder, and propelled backwards without reversing the engines. Adapted to light-draught vessels.

24. Clark, Standfield, & Co., London, England.

MODEL OF GRIDIRON FLOATING DOCK.

Report.—Commended for novelty of plan and design, and apparent commercial utility.

25. American Dredging Co., Philadelphia, Pa., U. S.

DREDGING MACHINES.

Report.—Two well-planned machines of general excellence and utility.

26. The Government of Bermuda.

FLOATING DOCK.

Report.—Commended for design, workmanship, and success in accomplishing the purpose for which it was intended.

27. American Ship-Windlass Co., Providence, R. I., U. S.

WINDLASS AND CAPSTAN MODELS.

Report.—Commended for excellence of mechanism.

28. F. E. Sickels, Providence, R. I., U. S.

APPLICATION OF STEAM TO STEERING SHIPS.

Report.—Commended for the method of applying steam power to steering vessels.

29. Nozikoff, St. Petersburg, Russia.

STEAM STEERING APPARATUS.

Report.—Commended for device in taking the power of steering the vessel from the shaft of the screw.

30. Fred. L. Stacy, Gloucester, Mass., U. S.

STEERING WHEEL.

Report.—Commended for utility and excellence of mechanism.

31. The John A. Roebling's Sons Co., Trenton, N. J., U. S.

WIRE ROPES.

Report.—Commended for superior make and material.

32. Dunckley & McBride, Melbourne, Victoria, Australia.

SASH AND LATHE LINES.

Report.—Superior articles, and almost of indefinite endurance, made from sheep intestines.

33. William Wall's Sons, New York, N. Y., U. S.

AMERICAN AND RUSSIAN HEMP STANDING RIGGING AND SMALL TARRED LINES.

Report.—Commended for superior manufacture and material.

34. B. Mill's Sons, Jersey City, N. J., U. S.

OAKUM.

Report.—Commended for superior quality, well tarred, and evenly picked.

35. Lawrence, Waterbury, & Co., New York, N. Y., U. S.

MANILA ROPE.

Report.—Manila ropes; a hawser of extraordinary size and superior manufacture.

36. Liverpool Spun Oakum Co., Liverpool, England.

MACHINE-SPUN OAKUM.

Report.—Commended for superior material and manufacture.

37. Robert H. Vyse, Brooklyn, N. Y., U. S.

RAW-HIDE ROPE.

Report.—Commended for good quality and good manufacture.

38. Tiburcio Villamarze, Tayabos, Spain.

HAWSER AND SMALL LINES OF PALM-TREE FIBRE.

Report.—Commended for anchorage purposes and novelty of material.

39. John T. Bailey & Co., Philadelphia, Pa., U. S.

AMERICAN HEMP TWINE SASH AND BELL CORDS.

Report.—Commended for good quality and, being machine made, the consequent reduction in price.

40. **Francisco Casado & Febrero, Seville, Spain.**

SMALL CORDS AND LINES OF SPANISH HEMP.

Report.—Commended for good material and good manufacture.41. **Peele, Hubell, & Co., Santa Mesa, Manila, Philippine Islands.**

MANILA ROPES.

Report.—Commended for good material.42. **Luis Garriga, Barcelona, Spain.**

TARRED AND UNTARRED RIGGING, SPANISH AND MANILA HEMP, LARGE AND SMALL LINES.

Report.—Commended for superior quality and good manufacture.43. **Fernandez Brothers & Co., Aguilas, Murcia, Spain.**

ROPE MADE FROM ESPARTO GRASS.

Report.—A cheap article of rope made from native grass for domestic purposes.44. **The Imperial Government of Brazil.**

NAVAL EXHIBITS.

Report.—Commended for the quality of the exhibits.45. **The Imperial Government of Russia.**

NAVAL EXHIBITS.

Report.—Commended for the quality of the exhibits.46. **Spanish Commission for Canary and Philippine Islands.**

MODELS OF SHIPS AND BOATS.

Report.—Representatives of vessels used in the Philippine Islands.47. **Royal Swedish Commission, Stockholm, Sweden.**

EXHIBIT OF COMMERCIAL AND FISHING BOATS USED IN SWEDEN.

Report.—An excellent exhibit of an important national industry.48. **David Damoizeau & Co., Paris, France.**

CHAIN CABLE WITHOUT WELD.

Report.—Commended for novelty of design and advantage of getting rid of the weld, which is a weak point in chain cables.49. **Bradlee & Co., Philadelphia, Pa., U. S.**

CHAIN CABLE, CRANE CHAINS, SHACKLES AND SWIVELS FOR ANCHOR CHAINS.

Report.—Commended for excellence of material and workmanship.50. **Coldbrook Rolling-Mills Co., St. John, New Brunswick.**

IRON SHIP KNEES.

Report.—Commended for good proportions and workmanship.

51. Thomas F. Rowland, Green Point, Long Island, N. Y., U. S.

IRON BUOY.

Report.—Commended for a new and useful mode of manufacturing wrought-iron or steel buoys or similar hollow vessels.

52. A. H. Hart & Co., New York, N. Y., U. S.

FLAX TWINES.

Report.—Commended for superior finish, evenness, strength, and pliability.

53. Eduardo Jackson, Manila, Philippine Islands.

MODEL AND PLAN OF A YACHT.

Report.—Commended for superior sea qualities, as shown by cylindroid, and well adapted to yachting requirements.

54. Coffin & Woodward, Boston, Mass., U. S.

CAPSTAN AND WINDLASS.

Report.—Commended for excellence of design and construction in their union power capstan and windlass.

55. United States Navy Department, Washington, D. C., U. S.

NAVAL EXHIBITS.

Report.—Commended for the quality of the exhibits.

SIGNING JUDGES OF GROUP XIX.

The figures annexed to the names of the Judges indicate the reports written by them respectively.

ISAAC NEWTON, 18, 29, 51.

JOHN W. GRIFFITHS, 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 15, 16, 17, 19, 20, 21, 22, 46, 47, 50, 53.

H. C. GOODSPEED, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 52.

F. H. RICH, 24, 25, 26, 44, 45, 48, 49, 55.

LUIZ DE SALDANHA, 6, 12, 13, 14, 23, 27, 28, 30, 54.

1

SUPPLEMENT TO GROUP XIX.

REPORTS
OF
JUDGES ON APPEALS.

JUDGES.

JOHN FRITZ, Bethlehem, Pa.
EDWARD CONLEY, Cincinnati, Ohio.
CHARLES STAPLES, JR., Portland, Me.
BENJ. F. BRITTON, New York City.
H. H. SMITH, Philadelphia, Pa.

COLEMAN SELLERS, Philadelphia, Pa.
JAMES L. CLAGHORN, Philadelphia, Pa.
HENRY K. OLIVER, Salem, Mass.
M. WILKINS, Harrisburg, Oregon.
S. F. BAIRD, Washington, D. C.

I. Thomas Shaw, Philadelphia, Pa., U. S.

BOAT-LOWERING DEVICE.

Report.—Commended for its simplicity and the certainty with which it performs its function.

SIGNING JUDGE OF SUPPLEMENT TO GROUP XIX.

The figure annexed to the name of the Judge indicates the report written by him.

CHAS. STAPLES, JR., I.

United States Centennial Commission.

INTERNATIONAL EXHIBITION,
1876.

REPORTS AND AWARDS

GROUP XX.

EDITED BY
FRANCIS A. WALKER,
CHIEF OF THE BUREAU OF AWARDS.

PHILADELPHIA:
J. B. LIPPINCOTT & CO.
1878.

Entered, according to Act of Congress, in the year 1876, by the
CENTENNIAL BOARD OF FINANCE,
In the Office of the Librarian of Congress at Washington.

SYSTEM OF AWARDS

[*Extract from Circular of April 8, 1876.*]

Awards shall be based upon written reports attested by the signatures of their authors.

The Judges will be selected for their known qualifications and character, and will be experts in departments to which they will be respectively assigned. The foreign members of this body will be appointed by the Commission of each country and in conformity with the distribution and allotment to each, which will be hereafter announced. The Judges from the United States will be appointed by the Centennial Commission.

* * * * *

Reports and awards shall be based upon inherent and comparative merit. The elements of merit shall be held to include considerations relating to originality, invention, discovery, utility, quality, skill, workmanship, fitness for the purposes intended, adaptation to public wants, economy and cost.

Each report will be delivered to the Centennial Commission as soon as completed, for final award and publication.

Awards will be finally decreed by the United States Centennial Commission, in compliance with the Act of Congress, and will consist of a diploma with a uniform Bronze Medal, and a special report of the Judges on the subject of the Award.

Each exhibitor will have the right to produce and publish the report awarded to him, but the United States Centennial Commission reserves the right to publish and dispose of all reports in the manner it thinks best for public information, and also to embody and distribute the reports as records of the Exhibition.

ORGANIZATION AND DUTIES OF THE JUDGES.

[*Extract from Circular of May 1, 1876.*]

Two hundred and fifty Judges have been appointed to make such reports, one-half of whom are foreigners and one-half citizens of the United States. They have been selected for their known qualifications and character, and are presumed to be experts in the Groups to which they have been respectively assigned. The foreign members of this body have been appointed

by the Commission of each country, in conformity with the distribution and allotment to each, adopted by the United States Centennial Commission. The Judges from the United States have been appointed by the Centennial Commission.

To facilitate the examination by the Judges of the articles exhibited, they have been classified in Groups. To each of these Groups a competent number of Judges (Foreign and American) has been assigned by the United States Centennial Commission. Besides these, certain objects in the Departments of Agriculture and Horticulture, which will form temporary exhibitions, have been arranged in special Groups, and Judges will be assigned to them hereafter.

The Judges will meet for organization on May 24, at 12 M., at the Judges' Pavilion. They will enter upon the work of examination with as little delay as practicable, and will recommend awards without regard to the nationality of the exhibitor.

The Judges assigned to each Group will choose from among themselves a Chairman and a Secretary. They must keep regular minutes of their proceedings. Reports recommending awards shall be made and signed by a Judge in each Group, stating the grounds of the proposed award, and such reports shall be accepted, and the acceptance signed, by a majority of the Judges in such Group.

The reports of the Judges recommending awards based on the standards of merit referred to in the foregoing System of Awards, must be returned to the Chief of the Bureau of Awards not later than July 31, to be transmitted by him to the Centennial Commission.

Awards will be finally decreed by the United States Centennial Commission, in compliance with the Act of Congress of June 1, 1872, and will consist of a special report of the Judges on the subject of the Award, together with a Diploma and a uniform Bronze Medal.

Upon matters not submitted for competitive trial, and upon such others as may be named by the Commission, the Judges will prepare reports showing the progress made during the past hundred years.

Vacancies in the corps of Judges will be filled by the authority which made the original appointment.

No exhibitor can be a Judge in the Group in which he exhibits.

An exhibitor, who is not the manufacturer or producer of the article exhibited, shall not be entitled to an award.

The Chief of the Bureau of Awards will be the representative of the United States Centennial Commission in its relations to the Judges. Upon request, he will decide all questions which may arise during their proceedings in regard to the interpretation and application of the rules adopted by the Commission relating to awards, subject to an appeal to the Commission.

A. T. GOSHORN,
Director-General.

[*Extract from Director-General's Address to Judges, May 24, 1876.*]

“The method of initiating awards which we have adopted differs in some respects from that pursued in previous exhibitions. In place of the anonymous verdict of a jury, we have substituted the written opinion of a Judge. On this basis awards will carry the weight and guarantees due to individual personal character, ability, and attainments, and to this extent their reliability and value will be increased. It is not expected that you will shower awards indiscriminately upon the products in this vast collection. You may possibly find a large proportion in no way raised above the dead level, nor deserving of particular notice. The standard above which particular merit worthy of distinction begins is for you to determine. In this regard I have only to express the desire of the Centennial Commission, that you should do this with absolute freedom, and when you meet with a product which you consider worthy of an award, we desire you to say, in as few words as you may deem suitable, why you think so.

“This, gentlemen, is all we ask of you in the Departments of Awards. Opinions thus expressed will indicate the inherent and comparative merits, qualities, and adaptations of the products,—information which the public most desires.

“Elaborate general reports and voluminous essays, though of great value as sources of general information, give little aid in determining the reliable or intrinsic merits of particular, individual products.

“The regulations which have been published divide the work of awards into three parts:

“1st. The individual work of the Judges.

“2d. The collective work of the groups of Judges.

“3d. The final decisions of the United States Centennial Commission in conformity with the acts of Congress.

“Each award will thus pass three ordeals, which, doubtless, will be ample and satisfactory.”

GROUP XX.

JUDGES.

AMERICAN.

CHARLES T. PORTER, Newark, N. J.
JOSEPH BELKNAP, New York, N. Y.
HORATIO ALLEN, South Orange, N. J.
CHARLES E. EMERY, New York, N. Y.

FOREIGN.

WILLIAM H. BARLOW, Great Britain.
FRANCIS REULEAUX, Germany.
NICHOLAS PETROFF, Russia.
EMIL BRUGSCH, Egypt.

E. N. HORSFORD was temporarily assigned from Group X. to assist in the examination of fire-hose and belting.

GROUP XX.

MOTORS, HYDRAULIC AND PNEUMATIC APPARATUS, Etc.

CLASS 550.—Boilers, and all steam or gas-generating apparatus for motive purposes.

CLASS 551.—Water-wheels, wind-mills.

CLASS 552.—Steam, air, or gas engines.

(For electro-magnetic engines, see Group XXV.)

CLASS 553.—Apparatus for the transmission of power,—shafting, belting, cables, gearing; transmission of power by compressed air, etc.

CLASS 554.—(See Group XIX.)

CLASS 555.—Implements and apparatus used in connection with motors; steam gauges, manometers, etc. (See also Group XXV.)

CLASS 560.—Pumps and apparatus for lifting and moving liquids,—water engines, hydraulic rams. (Class 551, in part.)

CLASS 561.—Pumps and apparatus for moving and compressing air or gas.

CLASS 562.—Pumps and blowing engines, blowers, and ventilating apparatus.

CLASS 563.—Pneumatic railways; pneumatic dispatch.

CLASS 563.—Hydraulic jacks, presses, elevators, lifts, cranes.

(For “meters,” see Group XXV.)

CLASS 564.—Fire engines,—hand, steam, or chemical; and fire-extinguishing apparatus,—hose, ladders, fire-escapes, etc.

CLASS 565.—Beer engines, soda-water machines, bottling apparatus, corking machines.

CLASS 566.—Stop valves, cocks, pipes, etc.

CLASS 567.—Diving apparatus and machinery.

CLASS 568.—Ice machines.

GENERAL REPORT

OF THE

JUDGES OF GROUP XX.

INTERNATIONAL EXHIBITION,
Philadelphia, 1876.

PROF. FRANCIS A. WALKER, *Chief of Bureau of Awards:*

SIR,—I herewith transmit the reports of the Judges of Group XX., which include the recommendations for awards; general reports on the exhibits referred to the group, by Messrs. Barlow, of England, and Emery, of the United States; and reports of Committees of the group on practical tests of the principal steam-boilers, fire-engines, and turbines exhibited.

Very respectfully,

HORATIO ALLEN,

Chairman Group XX.

GROUP XX.

MOTORS, HYDRAULIC AND PNEUMATIC APPARATUS, ETC.

BY CHARLES E. EMERY.

The exhibits referred to this group included in general the motors operated by vapors, gases, or fluids, and apparatus for the generation of steam; together with machinery for moving or operating upon gases and fluids, such as blowers and pumps; also, apparatus for the transmission of power and numerous incidental devices relating to the several subjects. Each of these branches was so very well represented that it has not been considered practicable or advisable to attempt a general description. It is proposed simply to put on record brief notes in relation to exhibits, or classes of exhibits, which, in the opinion of the writer, are of historical interest in connection with the growth of a particular industry; which suggest improvements for the future, or which, from some feature of importance or novelty, deserve special mention.

The Judges of Group XX. desired to make practical trials of several classes of the articles exhibited, and although circumstances prevented the design from being carried out to the extent intended while the services of the foreign members were available, a number of trials were made by committees, reports of which will be referred to hereafter.

HYDRAULIC EXHIBITS.

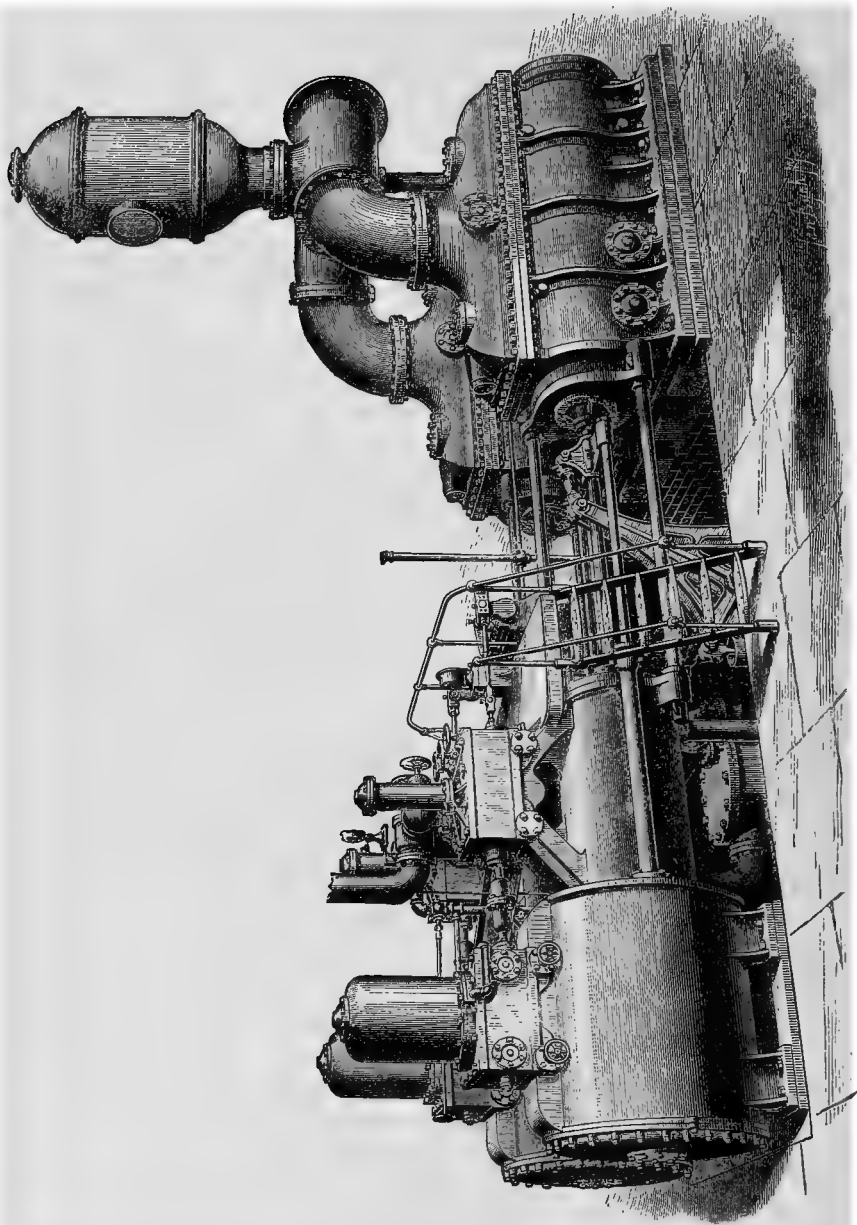
The hydraulic exhibits contained few features of novelty, but the display was, in most branches, very complete, and the arrangement such as to attract public attention, and give each exhibitor an opportunity to show his apparatus to the best advantage. The greater portion of these exhibits was located in the Pump Annex to Machinery Hall, in which was a pool or tank 160 feet long, 60 feet wide,

and 8 feet deep, located in the centre of the building, below the floor-level. The pool usually contained about five feet of water, and was connected with a series of channels or small canals, extending under the floor to different parts of the building, from which the various pumps received water, thereby obviating the necessity of small tanks for each exhibit. The water from the several power- and steam-pumps was discharged into the main pool at so many points, and with such variety and force in the direction of the streams, as to form a very interesting feature of the Exhibition. The discharge-pipes were generally carried over the passage surrounding the pool, and in some cases the water simply flowed from the ends of the horizontal pipes and fell in curves some 12 feet into the water. The ends of some of the pipes were turned downward, and one had a cup-shaped attachment to the bottom, over which the water flowed in an annular sheet. One exhibitor had several hose-nozzles arranged at the north end of the pool to throw water its entire length; another directed nozzles upward, and kept wet the roof of the ventilating gallery, about 70 feet above. There were in all some 70 streams playing into the pool, of which 8 were 6 inches in diameter or upward, and 22 were contracted nozzles, to give velocity to the issuing streams. The effect, when all the pumps were at work briskly, was quite pleasing, and would compare with natural scenes in animation and interest, if not in beauty. At the southern end of the pool an artificial waterfall, 36 feet wide and 32 feet high, was exhibited at certain hours of the day, the water for the purpose being supplied to an elevated tank by centrifugal pumps.

The pool was provided for in the plans of Messrs. Wilson and Pettit, the engineers and architects of the building; the arrangement of the exhibits being under the direction of the Bureau of Machinery.

PUMPING-ENGINES.

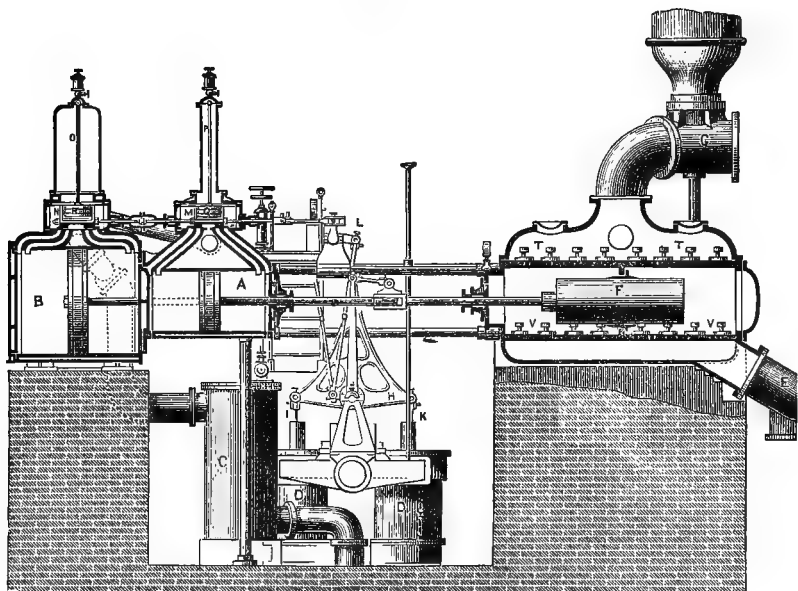
The largest and most expensive hydraulic exhibit was the pumping-engine for supplying the entire Exhibition grounds with water, which was furnished by Mr. Henry R. Worthington, of New York, and was located on the west bank of the Schuylkill, just outside the inclosure,—the stand-pipe, 120 feet high and 208 feet above the river, being within the grounds, near the Art Gallery. The engine was of the Worthington duplex type, with a capacity of 6,000,000 gallons daily. An exterior view of the same is shown in Fig. 1, and a sectional view in Fig. 2. There are two horizontal double-acting pumps with plungers $22\frac{1}{4}$ inches in diameter, arranged side by side on the same frame, each operated directly by a compound engine



WORTHINGTON DUPLEX PUMPING-ENGINE.

with steam jacketed cylinders 29 and 50 $\frac{1}{4}$ inches in diameter,—the strokes of engines and pumps being 4 feet. The smaller steam-cylinder is attached to the front head of the larger and has a central piston-rod connecting with the pump-rod through a cross-head, and two piston-rods from the larger cylinder pass outside the smaller and connect with the cross-head. There are two single-acting air-pumps, each 29 $\frac{3}{4}$ inches in diameter, with 24 inches

FIG. 2.



Worthington Duplex Pumping-Engine.

stroke, which are operated from the ends of a horizontal beam with vertical lever attached, receiving motion from one main cross-head. The main valves are plain slides operating over double-cylinder ports as described hereafter. The valves for both cylinders of each engine are arranged on the same stem by raising the chest of the smaller, and each valve is provided with a balancing piston. The valves of one engine are operated by bell-cranks directly from the reciprocating parts of the other, and no rotative movements with accompanying details are required. As previously stated, double cylinder ports are provided. The outer ones receive steam past the ends of the valve and admit it to the cylinder in the usual way. The inner ones communicate with the exhaust cavity of the valve only, and enter the cylinder at such distances from the ends that when steam is exhaust-

ing through one of the ports the main piston will run over and close it and cushion upon the vapor thereby inclosed, the outer port being at the time shut off by the main valve. Valves are provided to put the two cylinder ports at each end in communication to regulate the extent of cushioning. The pump-valves consist of rubber disks, arranged in chambers above and below the plungers. Each plunger runs without packing in a long grooved ring in a central diaphragm. In operation, one engine while in full action moves the valves of the other, when the pistons of the latter gradually begin to move, and finally attain full velocity as those of the first are checked by the steam-cushions and gradually come to rest,—the pump-valves meantime seating quietly. The first engine pauses a moment till the second engine admits steam when it commences a return stroke and the second comes to rest,—the action of one blending into that of the other as each alternately takes up the load,—the result being that the discharge is uniform, a uniform pressure is maintained in the main, and the pumps under heavy or light pressure operate without jar or noise.

The remarkable contrast between engines of this type and the well-known Cornish engines, both in construction and operation, will be appreciated from the above in connection with the engravings. In Cornish and other engines, non-rotative and rotative, in order to practically use steam with considerable expansion it is necessary to attach to the moving parts heavy masses of metal, which being accelerated, when pressures are high, absorb work, which is yielded up with a corresponding reduction in velocity as the operating pressures decrease. In the Worthington engines the weight and friction of moving parts are reduced to a minimum, and the elastic force of the steam practically acts upon the water column directly, whereby is secured simplicity of construction and smoothness of working, with a material reduction of frictional resistance, also freedom from the danger incident to handling the heavy weights in the original form of non-rotative engines. The expansion of steam in the Worthington pumping-engine is determined principally by the difference in the size of the compound cylinders, and is sufficient in connection with the freedom from jar and the low resistance of engines and pumps to secure duties which are quite high when it is considered that the maximum steam pressure so far employed is only 40 pounds. The official test of one of these engines at the Newark Water-Works, New Jersey, showed a duty of 77,358,478 pounds of water raised 1 foot with 100 pounds of coal. The engines show regular average yearly duties as high as 60,000,000, in which fuel necessarily expended on account of stoppages is included.

In Philadelphia a number of engines of different kinds are employed at the different pumping-stations. The following is extracted from the annual reports :

PUMPING-STATION.	TYPE OF ENGINE.	COST OF RAISING ONE MILLION GALLONS ONE FOOT HIGH.				
		1872.	1873.	1874.	1875.	1876.
		Cents.	Cents.	Cents.	Cents.	Cents.
Belmont	2 Worthington duplex:	7.00	7.68	7.08	7.84	7.07
Roxborough.....	{ 1 full Cornish and 1 Worthington duplex. }	9.90	9.92	9.19	10.30	9.51
Delaware	{ 1 high- and 1 low-press- ure rotative, and 1 Worthington duplex. }	13.20	13.14	14.35	12.98	12.69
Schuylkill	{ 2 full Cornish, 1 double- cylinder rotative, 1 bell-crank rotative. }	11.20	17.36	16.97	17.05	13.40
Germantown.....	1 high-pressure rotative.	36.20	.....	.....	.....	.....

On the whole, the evidence appears to be that the Worthington duplex engines give higher average performances than any other class of pumping-engines in use in the United States except those especially designed to secure economy of steam, and in comparison with those it is proper to consider differences in interest on first cost of engines and of their foundations, and also, in some cases, questions as to the ease of management and reliability for extended use under practical conditions.

It is stated that, when the load is thrown off from a duplex engine, as has happened by the breakage of a pipe, the steam-cushion prevents damage during the first stroke, and afterwards the action of the duplex valve-gear is to so shorten the strokes that no injury can occur. In the same building with the pumping-engine was exhibited a Worthington duplex pump similar to the engine, except that each pump-plunger was operated by a single cylinder.

Mr. Worthington exhibited also in the rooms of the American Society of Civil Engineers, in the west gallery of the Main Building, models, drawings, and descriptions of considerable historical interest. He undoubtedly originated and introduced the first direct-acting steam-pumps ever constructed,* and by his success created a demand for pumps of all kinds. A specimen was shown, complete, of his first form of pump as developed in the years 1840-44. In this pump the steam-valve is partially reversed by tappets and levers connecting with main piston-rod,—the throw being completed by a spring and arrow-headed bolt. The general features of this plan

* The Cornish and other pumping-engines without rotating parts are of course excepted.

have been repeated many times since. Mr. Worthington afterwards constructed several pumps in which the main valve was operated by an auxiliary piston, as in the more approved modern forms; a portion of one of this kind being exhibited. These pumps are said to have worked well, but were ahead of the times, and in 1849 the Worthington & Baker pump with relief-valve motion was brought out, which was very favorably received, and created the demand now so well supplied by many manufacturers. To this pump, it is believed, the *m*, or double cavity steam slide-valve, now universally used in steam-pumps, was first applied. It is employed with the ordinary arrangement of cylinder ports on an elevated face, but steam enters under the end of the valve, at the end of the cylinder opposite that supplied by an ordinary single cavity-valve when moved in the same direction. The pump consisted simply of a steam-cylinder and plunger-pump, with an arm on the piston-rod extended upward to operate tappets on the valve-stem. As the pump neared the end of the stroke, openings in the pump-plunger were uncovered, thereby admitting water from one side of the plunger to the other and relieving the engine of load, when the stroke was completed, by the expansion of the steam in the cylinder, with such velocity as to insure the operation of the steam-valve by means of the tappets. Ericsson is reported to have said of one of these pumps that it represented greater efficiency, for a given number of parts and quantity of material, than any machine he had previously seen. The largest pump constructed with this valve-gear had a capacity of 300,000 gallons per day, and was erected in 1854, to supply the city of Savannah with water. It was provided with an annular compound steam-cylinder, and was running regularly two years since. The sudden reversal of motion at the end of the stroke with this valve-gear made its application to larger engines not desirable. The plan of using a large number of small pump-valves was first applied in the year 1850, substantially as shown in Fig. 2, and the system in various forms is being adopted by manufacturers. As compared with the heavy double-beat valves usually employed in pumping-engines, the small valves require less lift, produce less jar, and offer less resistance to the passage of the water. The Worthington duplex engine was perfected about the year 1859, and from 1860 to 1876 no less than 80 were erected in different parts of the United States and Canada, with capacities varying from 500,000 to 15,000,000 gallons daily. For engines of moderate size, the two pumps are severally operated by cylinders of different sizes, the steam exhausting from one to the other through an intermediate receiver.

The type of pumping-engine designed and patented by Mr. E. D. Leavitt, and constructed by I. P. Morris & Co., of Philadelphia, was illustrated at the Exhibition by a drawing in the rooms of the American Society of Civil Engineers, previously mentioned. The engines are compound beam-engines, with a Thames-Ditton bucket and plunger-pump, and are especially designed to secure economy of fuel. The pump connects to one end of the beam, the main connecting-rod to the other. The bottoms of the high- and low-pressure cylinders are located close together at the centre of the frame, and their tops incline outward toward the ends of the beam, by which arrangement the strokes of the pump, of both main pistons, and the throw of the crank are equal. The cylinders are steam-jacketed. The main valves are of the gridiron pattern, and reduce the spaces in clearance, etc., to a minimum. The first engine of this kind was put in operation in Lynn (Massachusetts), in the year 1873, and showed, on trial, the remarkable duty of 103,923,215 pounds raised 1 foot high with 100 pounds of picked Lackawanna coal, with less than 8 per cent. refuse; the duty being based on the pressure in the main by gauge plus the pressure due to the height of gauge above water in the pump-well, increased by one pound for estimated resistances in suction-pipe, etc., and on the entire displacement of the pump, without any allowance for loss of action, which latter, by weir trials, was found to be 4 per cent.

A pair of these engines tested in Lawrence, Massachusetts, in 1876, showed an average duty of 96,186,979 foot-pounds for 100 pounds of Cumberland coal, the duty being estimated from actual quantities, except that the actual delivery over the weir at the reservoir was increased 5 per cent., as provided for by contract, to allow for loss of action in the pump. These results rival those obtained with the best English pumping-engines. A duty of about 93,000,000 was obtained previously with an engine at Lowell, designed by Mr. Robert Briggs, which was tested on the same basis. The principal dimensions of the Leavitt engines in operation at the time of the Exhibition are as follows:

	Lynn.	Lawrence.
Number of engines	1	2
Diameter of high-pressure cylinder, inches	17½	18
Diameter of low-pressure cylinder, inches	36	38
Diameter of pump-barrel, inches	26 $\frac{1}{10}$	26 $\frac{1}{8}$
Diameter of plunger, inches	18½	18½
Stroke of engines and pump, feet	7	8

A large working model of the Davey compound differential pumping-engine was exhibited by Messrs. Paulding, Kemble, & Co., of

West Point Foundry, New York. Usually the pump and compound cylinders of these engines are arranged horizontally on the same frame, with the smaller cylinder nearest the pump and its piston-rod connecting to the pump-rod through a cross-head, which also receives two rods from the larger cylinder extending alongside the smaller. Usually the main valves are plain slides, with considerable lap, having an equalizing port running through the metal outside the central cavity. The valve receives a so-called differential movement from an intermediate point in a lever, one end of which is moved, through suitable reducing levers, by the main piston, but in the opposite direction, and the other by a cataract engine. The latter consists simply of a steam-cylinder, the piston of which is connected to that of a regulating cylinder, in which a fluid is displaced from one end to the other through a graduated opening. The valve of the cataract engine also receives motion from the differential lever.

Let it be supposed first, that the main and cataract pistons are moving in the same direction, the latter slightly in advance, and tending to open the main valve, while the movement of the main piston tends to close it. If the pressure overbalances the load the main piston will run ahead and thereby cut off the steam-supply so that the stroke will be completed by expansion. In any case, before the main piston reaches the end of its stroke the valve of the cataract engine will be shifted so that the direction of that piston will be reversed, and, from the compound movements, the main valve will be shifted soon after, so that the motion of the main piston will also be reversed, and follow in the same direction as the cataract piston,—when the operations will be repeated. When the main valve is shifted near the end of the stroke, the main piston remains at rest, permitting the pump-valves to seat quietly. In case of accident, whereby the load of the engine is thrown off, the main piston will move ahead of the cataract engine, and steam be shut off.

This simple valve-gear, therefore, 1, distributes the steam; 2, regulates the expansion to suit the load; 3, secures the desired pause at the end of the stroke to permit the pump-valves to seat quietly; and, 4, acts as an efficient safety apparatus. Simple modifications of this valve-gear are applied to Cornish engines, and the various forms of single and compound engines. The system has been largely used in England, and has been introduced on the Pacific coast of the United States. Drawings were exhibited in the rooms of the American Society of Civil Engineers, by the Risdon Iron & Locomotive Works, of San Francisco, California, illustrating large pumping-engines, with the Davey valve-gear, in process of construction for mines in that

vicinity. Their introduction in the eastern part of the United States is being prosecuted by the exhibitors.

In connection with the subject of pumping machinery, the following extract from a monograph on the water-works of Philadelphia, from 1801-15, by Frederick Graff, C.E., communicated to the exhibit of the American Society of Civil Engineers, will be found of historical interest, as showing by comparison the advances made at the date of the Exhibition.

The paper first states :

"The first steam-engine of any considerable size appears to have been introduced into America and put to work about the year 1763, at the Schuyler Copper Mine, situate on the river Passaic, New Jersey. All of its principal parts were imported from England, and Mr. Hornblower (the son, it is believed, of the well-known steam engineer of that time) came to this country for the purpose of putting up and running the engine.

"About the year 1800 the manufacture of the engines for the Philadelphia Water-Works was commenced; and as late as the year 1803 we find five steam-engines only noticed as being in use in this country, as follows :

"Two at the Philadelphia Water-Works; one just about being started at the Manhattan Water-Works, New York; one in Roosevelt's Saw-Mill, New York; one in Boston; and a small engine used by Oliver Evans to grind plaster of Paris, at the corner of Ninth and Market Streets, Philadelphia.

"The engines for the Philadelphia Water-Works were manufactured by Nicholas Roosevelt, at works established by him near the Schuyler Copper Mine, above referred to."

Then follows an extract from a report made in 1800, setting forth the difficulties in boring the cylinder for the engine of the water-works on the Schuylkill at the foot of Chestnut Street. The paper continues :

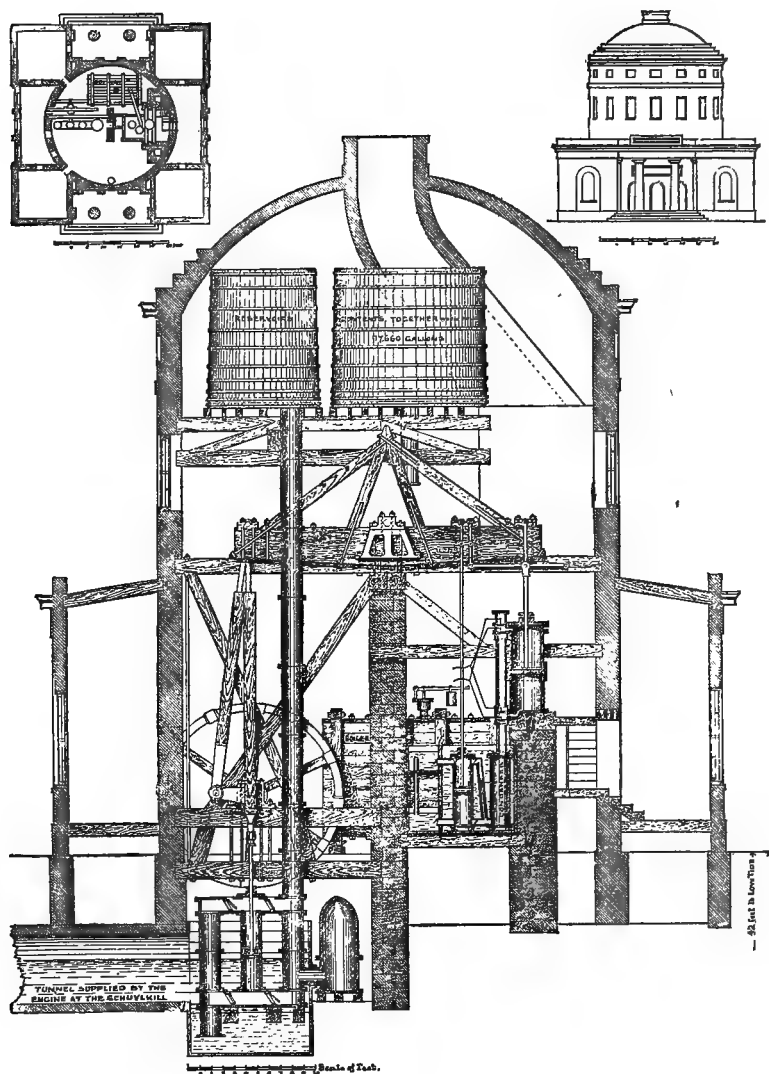
* * * * *

"The cylinder was $38\frac{1}{2}$ inches diameter and 6-feet stroke, and drove a double-acting pump $17\frac{1}{2}$ inches in diameter and 6-feet stroke.

"The engine at Centre Square, built about the same time and at the same place, had a steam cylinder 32 inches diameter and 6-feet stroke, and worked a double-acting pump of 18 inches diameter and 6-feet stroke, raising the water into tanks about 51 feet high.

"In both these engines the lever-beams, the arms and shafts of the fly-wheels, the bearings upon which the fly-wheels were supported,

FIG. 3.



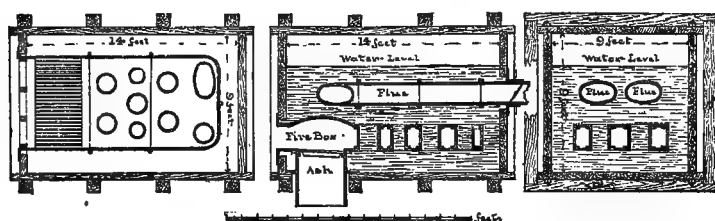
SECTION THROUGH THE ENGINE-HOUSE OF THE CENTRE SQUARE
WATER-WORKS, PHILADELPHIA.

Drawn by Frederick Graff from the original drawings and memoranda in his possession.

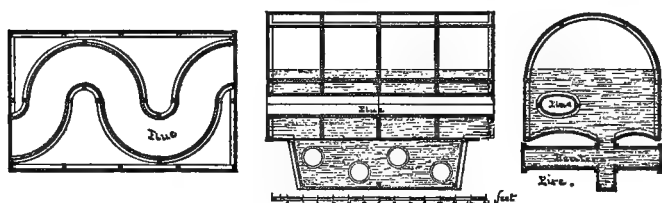
Building commenced, July, 1799. Commenced erecting the engine, February, 1800. Started the engine to supply the city, January 21, 1801. Supply from these works discontinued, September 7, 1815. Building taken down, 1827.

the hot wells, the hot and cold water pumps, the cold water cistern, and even the steam-boilers, were all made of wood. These latter were rectangular chests, made of white pine planks 5 inches thick ;

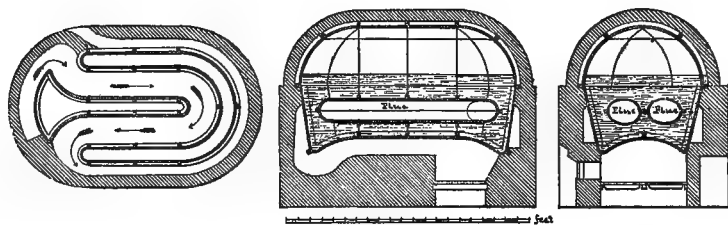
FIG. 4.



Plan and Sections of the Wooden Steam-Boiler used at the Centre Square Water-Works from 1801 to 1815.



Cast-Iron Boiler, Centre Square Water-Works, 1804.



Cast-Iron Boiler in use at the Schuylkill Engine-House, Philadelphia Water-Works, from 1803 to 1815.

they were 9 feet square inside at the ends and 14 feet long in the clear, braced upon the sides, top, and bottom with oak scantling 10 inches square, the whole securely bolted together by $1\frac{1}{4}$ inch rods passing through the planks. Inside of this chest was placed a fire-box 12 feet 6 inches long, 6 feet wide, and 1 foot 10 inches deep, with vertical flues, six of 15 inches diameter and two of 12 inches diameter; through these the water circulated, the fire acting around them and passing up into an oval flue situated just above the fire-box, carried from the back of the boiler to near the front, and

returned again to the back where it entered the chimney. This fire-box and flues appear to have been at first made entirely of cast-iron; then a wrought-iron fire-box was made, the flues still being of cast-iron; this not being satisfactory on account of the unequal contraction and expansion of the two metals causing leakage, eventually wrought-iron flues were also put in. [See Figs. 3 and 4.]

"Great advantage was at the time supposed to be gained by the non-conducting powers of the wood, and also by the vertical flues in the fire-box.

"By experiments made with the engines when the above described wooden boiler was in use, it was recorded that the engine at Chestnut Street, on the Schuylkill, while lifting the water to the height of 39 feet, and running at a speed of 16 revolutions per minute, raised 1,474,500 ale gallons of 232 cubic inches each in 24 hours, with a consumption of 70 bushels of Virginia coal. And the engine at Centre Square, raising the water 51 feet, pumped 962,520 ale gallons in 24 hours, with a consumption of 55 bushels of the same kind of coal; the pressure of steam in both cases being $2\frac{1}{2}$ pounds to the square inch.

"As might be expected, great difficulty was experienced in keeping these boilers steam-tight; accordingly, on December 1, 1804, a boiler with cast-iron shell, as well as flues, was put up, and another one, also of cast-iron, but of different form, was put in use March 10, 1806. The second of these, which was erected at the works on the Schuylkill, had semi-circular ends, was 17 feet long and 8 feet wide at the bottom, and 19 feet long and 10 feet wide near the top; the flame passed under the bottom and around the back into oval flues which pass through the boiler, returned, and passed around the sides outside the shell.

"The first had a semi-circular top, the ends being flat, and was erected at Centre Square. The fire passed under the boiler around heaters of peculiar construction, and through one flue of serpentine plan to the front of the boiler; this boiler had two sheets of wrought-iron upon the bottom, just over the fire, all the rest being cast-iron.

"These boilers remained in use until the steam-works at Fairmount were started, September 7, 1815."

It would require too much space to follow in detail the history of the pumping-engines in the United States from the time included in Mr. Graff's paper to the date of the Exhibition. Several important pumping-engines, which are interesting from peculiarities in construction, were put in operation during that period, of which it is probable but few will be duplicated.

In the year 1847, Mr. Erastus W. Smith, then superintendent of the Allaire Works, New York, designed an engine for the New Orleans water-works involving the very important and unusual modification of arbitrary motion of valves in the pump. This engine was erected and performed successfully.

Cornish "bull" pumping-engines were erected in Buffalo in 1850. After running a number of years extra plungers were applied, and the steam pressure was increased to increase capacity. These same engines were altered into compound rotative engines afterwards, for which the original construction was not well adapted.

Messrs. Sickles & Dickerson, in 1856-57, constructed engines for Hartford, Connecticut, and for Detroit, Michigan, designed to rectify the inequality of the crank movement as applied to pumping, and to secure in a superior degree the advantages due to the expansion of steam. The arrangement of the pumps of the Hartford engine has been described as follows: "The power was communicated through a pinion on the crank-shaft engaging a spur-wheel on either side of it. On each spur-wheel shaft were two cams; each cam gave motion to a set of pumps by means of bell-cranks; each set of pumps was composed of two pistons or boxes in one chamber or cylinder, one above the other, and moving independently of each other,—the piston-rod of the lower box passing through the upper piston-rod, which was made tubular." The cam motions were so contrived that each piston commenced before the other had completed its stroke. The pistons "commenced the stroke slowly, increasing to the uniform velocity, and then decreased for a little distance before stopping." There were, it will be seen, eight pumps distributed through the circle of rotation, but as they were operated by a single steam-cylinder, using a high degree of expansion, the result was not as expected. The mechanical difficulties with the Detroit engine were so great that it was abandoned and removed.

A beam pumping-engine, without rotative parts, was erected at the Brooklyn Water-Works about the year 1857, which was designed to use steam expansively in both ends of the cylinder. It became necessary, however, in order to secure even moderate expansion, to add mass in the form of heavy segments vibrated by connection to the main piston-rod. A rotative beam-engine erected at the works in 1869 operated so well that a duplicate of the original engine was altered to the same plan. The original design had two pump-buckets moving in opposite directions, in a continuation of the same pipe,—a system apparently so advantageous that it is worthy of further trial.

In the year 1861 a non-rotating pumping-engine, of unusual size,

having a capacity of 800,000 gallons per hour against a head of 170 feet, was erected at the Cincinnati Water-Works, from the designs of Mr. George Shields, engineer in charge. The main cylinder, air-pump, and main pumps are all in the same vertical line. The engine is very bold in design, and excellently constructed, but the mass in motion is comparatively so small that the operation is practically without expansion, like an enormous steam-pump. There are at Cincinnati, in addition to the above, several excellently-constructed rotative beam- and vertical pumping-engines; also a pair of horizontal high-pressure engines of the Western river steamboat style, applied for operating pumps. In a practical trial made in the year 1872, the latter were found to give more economical results than either of the low-pressure engines.

An interesting engine was erected several years since at the High Service Pumping-Works, Providence, Rhode Island, by Mr. George H. Corliss, the celebrated engine-builder. Five horizontal steam-cylinders and five horizontal steam-pumps are arranged radially, with pistons connected to a crank on a central vertical shaft to regulate the strokes,—no fly-wheel being employed. The work heretofore available at that station has not been at all sufficient for the size of the engines, but the system as such appears to offer advantages in obtaining uniformity of flow. During the Exhibition, Mr. Corliss was perfecting, by careful experiment, a compound engine with horizontal steam-cylinders.

Excellent results have been obtained in some locations with simple horizontal engines connected to horizontal or vertical pumps, and in engines of this class at Pittsburgh the lever connections are arranged to reduce the velocity of the pump-piston in relation to that of the steam-piston at the latter part of the stroke, so as to permit expansion.

The first important compound pumping beam-engine in the United States was erected in the year 1872, at the Schuylkill Works, Philadelphia, and was built from designs of Mr. Frederick Graff, chief engineer of the Water Department. The original engine of this type was, it is believed, constructed by Messrs. Simpson & Co., of the Grosvenor Works, Pimlico, England, and erected at the Bristol and Richmond Water-Works, in the year 1848. The system has been since extensively adopted both in England and this country. The Leavitt engines and the engine at Lowell, previously mentioned, are of this general type, and a pair of engines of this kind, with Corliss valves, which were in process of construction by the Quintard Iron Works, New York, during the Exhibition, have since been erected

in Chicago, and gave, on trial, tested singly, an average duty of 97,575,050 foot-pounds per hundred pounds of coal.

During the period mentioned there were erected a considerable number of excellent engines of the well-known Cornish and beam-rotative types. A large Cornish engine was put in operation in Providence, Rhode Island, while the Exhibition was in progress.

The number of Worthington and Leavitt pumping-engines erected previous to the Exhibition has been stated already in connection with a description of the exhibits.

STEAM-PUMPS.

The steam-pumps formed a very large portion of the exhibit in the Hydraulic Annex. A complete description of the display, or of all its special features, would be tedious. The nature of the exhibit as a whole, and the importance of the steam-pump industry, may be judged from the accompanying list of the pumps shown by two of the more prominent exhibitors, in connection with which the more interesting features of the valve-gearing of direct-acting pumps will be briefly explained.

The Knowles Steam-Pump Works, Warren, Massachusetts, exhibited the following: One pump, for water-works, with steam-cylinder 42 inches in diameter, and water-cylinder 22 inches in diameter, the stroke of piston being 36 inches; one pump, with composition-covered plunger, 18×7×24,—the figures for brevity referring to the diameters of the steam- and water-cylinders or water-plungers, and length of stroke in the order named; one plunger-pump, 24×10×24; a vertical syrup-pump, with composition plunger, 16×10×24; one oil-line pump, 14×4×24, with ball pump-valves; one local oil-line pump, 6×3×7, with ball pump-valves; one blowing-engine, 18×48×48; one air-pump, with leather valves, 10×20×16; one vertical mining-pump, Cornish pattern, 10×8×48. Also other pumps of various sizes, designed for fire purposes, for lifting water to tanks, for feeding boilers, for attachment to locomotives, and other purposes; there being thirty-four pumps in all, several of the smaller ones being nickel-plated. All were of tasteful design, with parts finished to gauges with the greatest accuracy; finished bolts and nuts were used throughout, and all the joints ground to go together without packing of any kind. The value of this exhibit, as shown by the price-list, exceeded \$27,000.

The George F. Blake Manufacturing Company, Boston, Massachusetts, exhibited the following: One 20×18×24 wrecking-pump, capacity 2600 gallons, at 100 strokes per minute; one 20×14×24

water-works pump, capacity 1,000,000 gallons per 24 hours; one $18 \times 9 \times 36$ mining-pump, with patent removable water-cylinder, for gritty or bad water; two fire-pumps, one $20 \times 9 \times 24$, and one $14 \times 7 \times 12$; one $18 \times 5 \times 18$ oil-line pump; one $14 \times 2 \times 12$ hydraulic pressure pump; two double-plunger mining-pumps, one $28 \times 16 \times 24$, and one $20 \times 10 \times 24$; one $8 \times 8 \times 8 \times 10$ combined air and circulating pump, for marine-engines; one $16 \times 18 \times 12 \times 24$ combined vacuum- and water-pump, for vacuum-pans; one $6 \times 4\frac{1}{2} \times 7$ vertical, deep-well pump, piston pattern, double-acting; three sizes of combined pumps and boilers, complete for railroad water-stations, and a large variety of small pumps, such as boiler-feeders, tank-pumps, pumps for breweries, refineries, tanneries, gas-works, soap-factories, etc. The exhibit comprised five car-loads of material, and its value, per price-list, was about \$24,000. All the work was well finished and of a substantial character, well adapted for the purposes intended.

Most of the pumps exhibited were of the direct-acting type, though a few crank-pumps were shown. The term direct-acting pump is used to signify not only that the steam- and water-pistons are directly connected, but that the movement of the main valves is derived from that of the main piston, directly or indirectly, without the use of rotary motion to regulate the stroke or operate the valves. One kind of direct-acting pump stores up energy by compressing a spring, or the like, during part of the stroke, and releasing it to move the valve. A pump of this kind exhibited had details very similar to the original Worthington pump of 1840, previously referred to. Another pump, exhibited in Brewers' Hall, had a single-acting steam-piston, instead of a spring, to complete the stroke of the valve; and the initial movement was made by a cam and series of links in a very ingenious manner.

In most of the direct-acting pumps, however, auxiliary steam-pistons are provided to move the main valve. In operation, the main piston first moves the valve of the auxiliary cylinder, when the piston of the latter moves the main valve; and, as the movements are successive, with the better class of valve arrangements of this kind, one piston or the other will always be in position to act, and the pump will start and operate by simply admitting steam, or even water under pressure. A great amount of study and experiment have been expended on valve-gear of this character, and the problem is a difficult one, notwithstanding the apparent simplicity of the apparatus. In operation the main piston, as it nears the end of its stroke, must by a tappet connection, or equivalent, move the valve of the auxiliary cylinder, and the auxiliary piston move the main valve quickly

enough to prevent the main piston from striking the cylinder-head, and yet not so suddenly as to produce injurious jars in the pump end. This requires that the valve operating the piston shall start promptly when steam is admitted to it; that it shall move for a time at a higher velocity than the main piston; and that then the mass of matter in motion, consisting of the auxiliary piston and main valve, shall be suddenly brought to rest without noise, if possible, and at least without destructive jar. Each one of these requirements has been met in various ways. The initial movement to the auxiliary valve has been given by tappets and reducing arms, variously arranged, both inside and outside the cylinder, while in other cases no tappet at all is used, but the main piston acts as a valve, to cause steam to give the initial movement. The problem of starting and controlling the auxiliary pistons has led to many curious arrangements of passages, combined with all kinds of cushions, both internal and external. These plans could not be made plain without a number of engravings and extended explanations, but the general principles are more easily explained than the same can be carried into practical operation. A common plan is to provide separate steam- and exhaust-ports for the auxiliary cylinders, and when the auxiliary piston nears the end of its stroke, it runs over and closes its exhaust and cushions on the inclosed steam. Steam is admitted again, either by carrying a double port to the valve-face, as shown in the Worthington pumping-engine, and patented for auxiliary cylinders by Mr. L. J. Knowles, or but one port is provided in the valve-face and two in the cylinder, the outer one of the latter closed by a check-valve, which opens toward the cylinder when steam is admitted to the port. The latter plan, substantially, is used in the Blake pumps. Others use ordinary slide-valves for auxiliary valves, and have separate cushioning arrangements inside or outside of the steam-chest. In another arrangement the main piston passes over a small opening, which admits steam from the cylinder to move the auxiliary piston. Many pumps of this class will not start in all positions. In the Knowles pump the lower surface of the auxiliary piston acts as the auxiliary valve, and by giving this piston a slight rotary movement, steam- and exhaust-ports are opened, to cause longitudinal movement, such movement closing both the steam- and exhaust-ports, near the end of the stroke, so as to check the velocity both by cushioning and expansion; and, in addition, if the piston moves beyond a certain point, steam is admitted to check and return it slightly. The reverse rotary movement opens reverse ports, and the operation is repeated. In the Knowles pumps, and those exhibited by Mr. William D. Hooker, of Dedham, Massachusetts, double ports are provided at each end of

the main cylinder, as in the Worthington pumping-engines, by which means the main pistons are gradually brought to rest by the steam-cushions, the pump-valves seat quietly, economy is secured, and greater speed may be attained.

A compound steam-pump, with cylinders in line, was shown by Mr. A. Carr, of New York, and an annular cylinder compound steam-pump, by Messrs. Hillis & Jones, of Wilmington, Delaware.

A number of vacuum-pumps were exhibited, all founded on the principle of the original Savery pumping-engines, but with self-acting valves. In all cases there are dual chambers, which are provided with induction and eduction water-valves. To explain the operation: suppose a partial vacuum in one chamber, with water entering it, and steam in the other chamber forcing water out. The water entering the first chamber reduces the vacuum, and at the same time the water in the second chamber is lowered, so that a jet of water enters the steam and produces such rapid condensation that the pressure becomes less than in the first chamber, and an automatic steam-valve, operated by the difference of pressure in the two, is shifted, and admits steam to force the water out of the first chamber, while the steam in the second chamber is at once condensed, forming a vacuum, thereby causing water to rise in it, when similar operations are repeated. Some of the exhibitors provide a small check-valve in each chamber, for the avowed purpose of interposing a film of air between the steam and water. In the pumps exhibited by Nye, Gourlay, & Co., of Chicago, Illinois, the cylinders are lined with wood, to reduce condensation. The "Pulsometer" pumps, exhibited by Mr. J. A. Grosvenor, of Jersey City, New Jersey, are of a tasty and pleasing design. The New York Hydraulic & Drainage Company arranges a number of vacuum-cylinders in gangs, and operates the steam-valves at regular intervals by external power. The pump-valves provided with these cylinders are given an unusually large area to reduce resistances.

DUTY OF PUMPS.

The duty of a vacuum-pump may be readily ascertained by simply noting the height of lift, and the initial and final temperatures of the water lifted. All the heat of the steam not expended in work enters the water, and the work performed lifts the same water. The difference in temperature gives very nearly the number of heat-units imparted to each pound of water lifted, and each pound of water so heated is lifted a certain number of feet high, so the result may be expressed readily in foot-pounds per heat-unit, and this may be

changed into terms of the conventional duty of pumping-engines by simply fixing upon a standard to represent the number of heat-units imparted to water by one pound of coal. Inasmuch as the duty of pumping-engines is conventionally expressed in the number of foot-pounds obtained by the consumption of 100 pounds of coal, and as a pound of coal in a good boiler will evaporate over nine pounds of water at such pressure as to impart 10,000 heat-units to the water, or 1,000,000 heat-units for 100 pounds of coal, the writer has proposed the latter as a convenient basis of comparison, since the number of foot-pounds per heat-unit evidently expresses also the duty in millions of foot-pounds per 100 pounds of coal. For ordinary comparisons, the number of millions duty equals the lift divided by the difference between the initial and final temperatures of the water. For more accurate computations, the divisor should be increased by the number of heat-units expended for work per pound of water lifted, which equals the height divided by 772. The height preferably should be calculated from the indications of a pressure-gauge at the bottom of the discharge-pipe, so as to include frictional resistances. If D = duty in foot-pounds per 100 pounds of coal, H = the height of lift per gauge, and t and T = the initial and final temperatures respectively, then

$$D = \frac{1,000,000 H}{T - t + .0013 H}.$$

Arrangements have been made by the writer to use the same basis in testing pumping-engines, by discharging water from the hot well into the suction of the main pumps, and noting the resulting increase of temperature with delicate thermometers.

A vacuum-pump tested by the writer in 1871 gave a duty, on the above basis, of $4\frac{7}{10}$ millions; one tested by Mr. J. F. Flagg at the Cincinnati Exhibition in 1875, reduced to the same basis, gave a maximum duty of $3\frac{25}{100}$ millions. Several vacuum- and steam-pumps tested on this basis at the suggestion of the writer about two years since, gave duties reported as high as 10,000,000 to 11,000,000, the very small steam-pumps doing no better apparently than the vacuum-pumps, which is by no means surprising. Elaborate experiments made with steam-pumps at the American Institute Exhibition of 1867,* showed that average-sized steam-pumps do not, on the average, utilize more than 50 per cent. of the indicated power in

* See Report of Messrs. Holmes, Selden, and Emery, Judges, etc., *Transactions American Institute*, 1867-68.

the steam-cylinders, the remainder being absorbed in the friction of the engine, but more particularly in the passage of the water through the pump. Again, all ordinary steam-pumps for miscellaneous uses require that the steam-cylinder shall have 3 to 4 times the area of the water-cylinder to give sufficient power when the steam is accidentally low; hence, as such pumps usually work against the atmospheric pressure, the net or effective pressure forms a small percentage of the total pressure, which, with the large extent of radiating surface exposed and the total absence of expansion, makes the expenditure of steam very large. One pump tested by the writer required 120 pounds weight of steam per indicated horse-power per hour, and it is believed that the cost will rarely fall below 60 pounds; and as only 50 per cent. of the indicated power is utilized, it may be safely stated that ordinary steam-pumps rarely require less than 120 pounds of steam per hour for each horse-power utilized in raising water, equivalent to a duty of only 15,000,000 foot pounds per 100 pounds of coal on the same basis adopted for the vacuum-pumps. With larger steam-pumps, particularly when they are proportioned for the work to be done, the duty will be materially increased.

FIRE-ENGINES.

Full descriptions of the construction and performance of the steam fire-engines are given in the report hereto appended, on trials of these engines made under the direction of a committee of the group.

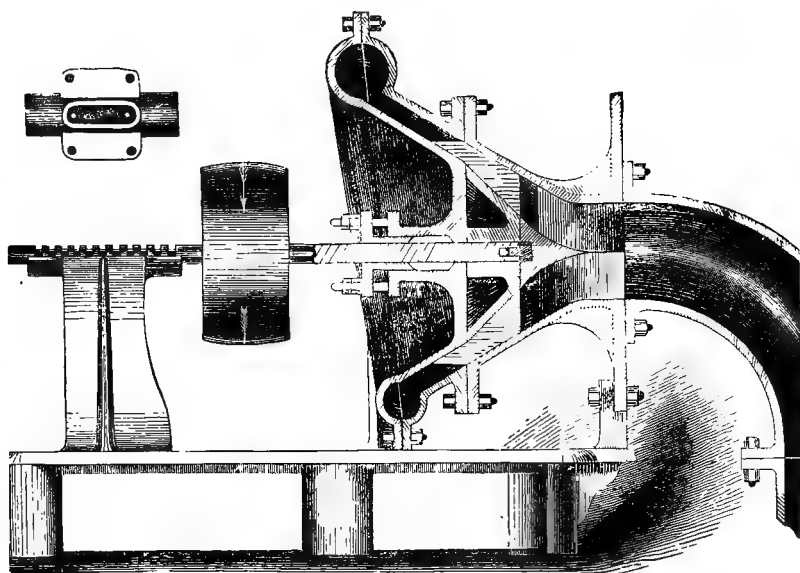
The exhibit of chemical fire-engines, fire-extinguishers, etc., was quite complete. In one of the latter, exhibited by Messrs. Murphy & Harle, of Montreal, Canada, air was compressed above the water to avoid the damage resulting from the escape of the materials used for the generation of carbonic acid gas. The well-known extensible fire-ladder of Mrs. Scott-Uda was also exhibited.

CENTRIFUGAL PUMPS.

The two centrifugal pumps, for lifting water into the tank for the waterfall, together with the engines operating them, were furnished by Messrs. William D. Andrews & Brother, New York. One pump, with a scroll-shaped case, had a capacity of 7000 gallons per minute, at a speed of 285 revolutions per minute. It was operated through two leather belts, with V-shaped sections, by an oscillating engine, with a cylinder of 20 inches in diameter and 15 inches stroke, running 150 revolutions per minute. The other pump, with a cylindrical case, had a capacity of 8000 gallons per minute, at a speed of 270 revolu-

tions per minute. It was operated through one leather belt, of V section, by an engine similar to that above referred to.

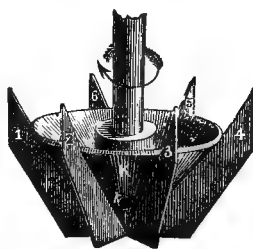
FIG. 5.



"Anti-Friction" Centrifugal Pump, Wm. D. Andrews & Bro.

The pump first above referred to was of the type designated by the manufacturer the "Anti-Friction Pump," of which a longitudinal section is shown in Fig. 5, and a perspective view of the wheel in Fig. 6. Openings, *k*, through the cone-shaped disk serve to balance the pressure on the two sides of the latter, and nearly neutralize the longitudinal thrust. Water passes from the suction-pipe through the wheel without abrupt changes of direction. The scroll-shaped discharge-pipe keeps the water in motion in nearly the same direction in which it leaves the wheel, and the energy stored up in the mass of water at its high velocity is utilized in urging forward the column. The results of the trial of one of these pumps, made in the year 1870, are shown in the following table:*

FIG. 6.



Wheel of Centrifugal Pump shown in Fig. 5.

* Report of Messrs. Emery, Pierce, and Magee, Judges, etc.—*Transactions American Institute*, N. Y., 1870-71.

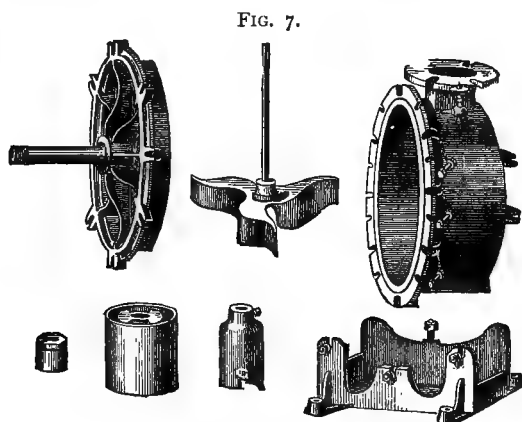
NUMBER OF EXPERIMENT.	DURATION OF EXPERIMENT.	REVOLUTIONS OF PUMP PER MINUTE.	GALLONS OF WATER DELIV- ERED PER MINUTE.	AVERAGE HEAD.	DYNAMOMETER HORSE-POWER.	NET HORSE- POWER.	PERCENTAGE UTILIZED.
	Seconds.						
1.....	30	552	1,204	19.55	9,752	5,949	61.00
2.....	30	526	1,105	19.55	8,323	5,463	65.64
3.....	40	489	863	19.47	5,689	4,247	74.64
4.....	40	552	1,293	19.75	10,000	6,454	64.54
5.....	40	529	1,279	19.75	9,117	6,385	70.02
6.....	40	497	931	19.50	7,163	4,687	65.44

The pump tested had a discharge orifice of 6 inches diameter; the water was received from the side of a large tank, and was delivered under a head varying, for the different experiments, from $19\frac{1}{2}$ to $19\frac{3}{4}$ feet. The lower part of the discharge-pipe was 6 inches in diameter, but it rapidly expanded to 12 inches diameter, which size was continued up to a tank about 3 feet square, over one side of which the water flowed into a chute, so suspended that the current could be quickly directed either into a measuring-tank or back to the receiving-tank. The pump was driven by a steam-engine, through a countershaft carrying one of Neer's dynamometers.

It was considered that the results shown in the table should be increased, for the reason that the belting got wet and had to be made very tight; but as this was a matter of estimate, a column referring thereto in the original table has been omitted. The net horse-powers shown were calculated from the weights of the water and the heights lifted, no allowance being made for friction in the pipe. Without correction the percentages utilized are quite high. The highest recorded efficiency we have observed is that of the large Appold pump at the London Exhibition of 1862. From the report of D. K. Clark, it appears that that pump lifted about 16,000 gallons of water 6 feet high per minute, utilizing 73.74 per cent. of the indicated power of the engine. Allowing 10 per cent. for the friction of the engine, the pump itself utilized nearly 82 per cent. of the power applied. The water was measured by weirs, and was used over and over again, whereby air was liable to be carried through and to reduce the weight lifted, which was obviated in the test above referred to by the use of tanks.

The other centrifugal pump used to supply water for the waterfall, as referred to above, was known as the "Cataract" pump. Perspective views of the wheel and case when separated are shown in Fig. 7, from which it will be seen that the construction is very simple. The

shape of the blade resembles the ogee form developed by Rankine.* This pump operated throughout the Exhibition very effectively, but its comparative efficiency is not known.

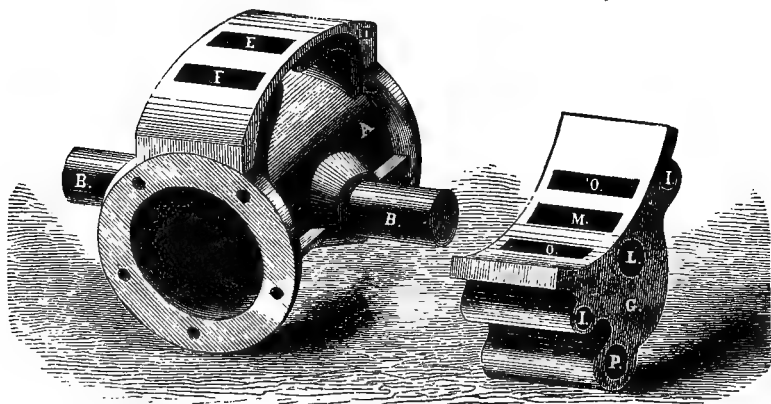


"Cataract" Centrifugal Pump, Wm. D. Andrews & Bro.

The engines used for operating the Andrews pumps are of the oscillating type, the distribution of steam being effected by an arc-

FIG. 8.

FIG. 9.



Cylinder and Steam-Chest of Oscillating Engine, Wm. D. Andrews & Bro.

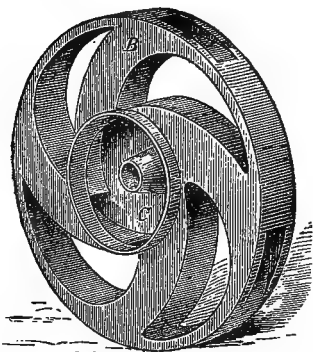
shaped valve-seat on the bottom of the steam-cylinder, concentric with the trunnions, with the ports operating, as the cylinder moves, in connection with passages in a valve-face on a stationary chest supported in the frame. The construction of the cylinder and chest will be

* See Parson's paper, *Proceedings (British) Institute of Civil Engineers*, vol. xlvii. p. 267.

understood by reference to Figs. 8 and 9. The engines are remarkably simple and compact, but no provision is made for securing economy by the expansion of steam.

The centrifugal pumps exhibited by Messrs. Heald & Sisco, of Baldwinsville, New York, operated efficiently at the Exhibition, and gave excellent results in practical use. The form of wheel preferably employed is shown in Fig. 10. The ring around the receiving opening on the side runs closely in a recess inside of the case. This pump requires a slower speed than many others, for which reason it has been used by the writer as a circulating-pump for several small steamers, and operated by direct connection to a small engine. This pump has given good results on trial, but these have never been published, and are not accessible.

FIG. 10.



Disk of Centrifugal Pump, Heald & Sisco.

An efficient pump was also exhibited by Messrs. White, Clark, & Co., also of Baldwinsville, New York; and a number of manufacturers of hand-pumps, hereafter referred to, had centrifugal pumps of the ordinary pattern in operation, but which possessed no features of special interest.

Centrifugal pumps of excellent design were exhibited also by Messrs. Neut & Dumont, of Paris, France, and by Gwynne & Co., of London, England.

Messrs. J. & H. Gwynne, of the Hammersmith Iron-Works, London, England, exhibited a highly-finished model, illustrating the centrifugal pumping machinery used in the reclamation of the Ferrara Marshes in Northern Italy, which is by far the largest pumping machinery of any kind ever constructed. There are 8 pumps, arranged in four pairs, each pair being driven by a compound engine. The pumps have 5-foot disks, and discharge-pipes 54 inches in diameter. The cylinders of each engine are respectively $27\frac{3}{4}$ and $46\frac{5}{8}$ inches in diameter, the stroke being 27 inches; the mean lift is 7 feet 3 inches, the maximum 12 feet. The capacity of the 8 pumps at mean lift is 57,000 gallons per minute, or 656,640,000 gallons per day. This would supply a stream 135 feet wide and averaging 3 feet deep, running uniformly at a speed of 2 miles per hour, which is much greater than the summer flow of many well-known rivers,—that of the Thames, England, for instance.

Some interesting examples are available showing the application of centrifugal pumps to dredging operations. In a paper by General Q. A. Gillmore, U. S. Engineers,* are recorded the results of using such a pump in deepening the channel over the bar at the mouth of St. John's River, Florida. The paper states that "upon this bar the ocean swell, which constantly prevails, is of such exceptional magnitude and violence, that the usual method of dredging into lighters or scows ordinarily pursued in still water is entirely impracticable." An Andrews pump was used with suction- and discharge-pipes 9 inches in diameter, which was operated usually at about 315 revolutions per minute. The paper states: "This speed in the No. 9 pump is equal to the work of raising 3000 gallons of clear water per minute, 30 feet high, through a 9-inch straight vertical pipe. The actual height raised above the water on the St. John's bar varies with the amount of sand taken on board, from 10 to 11 feet, but as the pipes are 50 feet long, with bends, and are in two branches instead of one, and as a mixture of sand and water is heavier and more impeded by friction than clear water, the loss by friction from all these causes combined reduces the useful work of the pump considerably below the average attainable under more favorable conditions. For these reasons, although 200 revolutions of the pump-disk per minute will easily raise 3000 gallons of clear water 12 feet high through a straight vertical 9-inch pipe, 300 revolutions are required to raise 2500 gallons of sand and water 11 feet high through the two inclined suction-pipes having two turns each, discharged through a pipe having one turn. To prevent the ends of the suction-pipes being lifted off the bottom by the pitching of the boat, and as a precaution against accident, a portion of each pipe is made flexible, being composed of 6-inch rubber hose stretched over a coil of wire. In addition, the ends are loaded with an iron frame or drag, each weighing about 250 pounds, which is intended to move flat along the bottom during the operation of dredging. To the under surface of this frame, directly below the mouth of the pipe, a number of teeth or knives are attached to stir up the sand and aid its entrance into the pipes." . . . "The proportion of sand that can be pumped depends greatly upon its specific gravity and fineness. The calcareous and argillaceous sands flow more freely than the silicious and fine sands and are less liable to choke the pipe than those that are coarse. When working at a high speed, 50 to 55 per cent. of sand can easily be raised through a straight vertical pipe, giving for every 10 cubic yards of

* Van Nostrand's *Eclectic Engineering Magazine*, September, 1872.

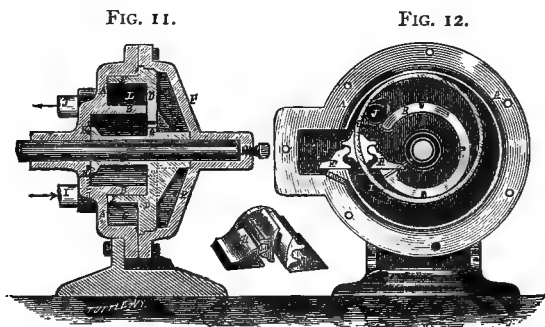
material discharged 5 to $5\frac{1}{2}$ cubic yards of compact sand. With the appliances used on the St. John's bar, the proportion of sand seldom exceeded 45 per cent., generally ranging from 30 to 35 per cent. when working under the most favorable conditions." An accompanying tabular statement shows that the average number of cubic yards removed per minute during the time the dredge was in operation varied from .73 to 1.12 yards, and that the cost varied from \$0.26 to \$1.22 per yard, the average cost for 128 days' work being about \$0.67 per yard.

In the improvement of Galveston harbor, Major Howell, U. S. Engineers, employs a centrifugal pump to fill the gabions with sand after they are located in place.

Captain Eads, at the date of writing, has just completed a large dredge, provided with a 30-inch centrifugal pump, designed to regulate and maintain the channel between the jetties at the mouth of the Mississippi River.

ROTARY PUMPS.

Most of the rotary pumps exhibited were in principle equivalent to a pair of spur-gear wheels, with coarse pitch inclosed in a case, the teeth of one operating as the wheels roll together to displace the fluid between the teeth of the other, substantially as shown in Figs. 15 and 16 in the report of the "Trial of Steam Fire-Engines," hereto appended. As is well known, the appearance of these pumps may be much varied by altering the number and shape of the projections;



Bagley & Sewall Rotary Pump.

which correspond with the teeth in the above general description. A number of fans used for the displacement of air, showing modifications of the above system, are illustrated under the head of "Blowing Machinery," *q. v.* There were also several small pumps,

both American and foreign, with eccentric disks and vibrating abutments, and others with arms sliding through the disks. The only rotary pump with special novel features was that exhibited by Messrs. Bagley & Sewall, of Watertown, New York (the L. D. Green patent), which is illustrated in Figs. 11 and 12. An eccentric ring, E, secured through a disk, D, to the main shaft runs externally in contact with the inside of the pump-case and internally in contact with the exterior of a stationary ring B. The receiving port I is located in the side of the case below a sliding abutment H, and a delivery port J is in a corresponding position above. Between the abutment and eccentric are tumblers, which adapt themselves to all movements, and secure tightness. The displacement is alternately between the eccentric and case, and the eccentric and inner ring, the latter being made sufficiently deep to maintain a uniform flow of fluid.

PROPELLER PUMPS.

The Hydrostatic and Hydraulic Company, of Philadelphia, Pennsylvania, exhibited the Shaw compound propeller pump, consisting simply of small propeller blades revolving in a pipe between similar stationary blades of reverse pitch, the currents thereby being forced upward in a spiral direction.

In the double propeller pump exhibited by Geo. A. Follensbee, of Lewiston, Maine, the vanes of two series of propellers on parallel shafts and running in opposite directions act alternately on the water and urge it directly forward without the spiral movement.

The efficiency of propeller pumps as compared with centrifugal pumps is not known.

DOMESTIC PUMPS.

The space on the wall side of the west aisle, in the Pump Annex, was for about two-thirds the length of the building occupied by three exhibits of pumps for domestic and factory uses, and considerably more space was used by these and other exhibitors in other parts of the building.

The invention of pumps is attributed to the Egyptians, before the Christian era, but there could have been no rational explanation of the action of the suction-pump until about 1643, when Torricelli explained the true nature of a vacuum. The material generally employed for the first pumps—wood—is still largely used for such purposes; even the quaint pump-logs of our fathers are seen on the advance lines of civilization. More shapely forms, requiring less material, are, by the aid of modern tools, manufactured largely in

districts where wood is cheaper than iron. Of this class the exhibit of Messrs. Biggs & Wells, of La Fayette, Indiana, were good examples. The Toledo Pump Company showed improved forms, in which the inner cylindrical surface, which receives the wear of the bucket, was lined with various materials suited to the kind of water: for instance, cast-iron enameled, but usually thin copper, lapped at the joints, so as to expand and contract with the wood. The application of iron in pump-construction was commenced in some of the earlier pump-factories by applying iron tops to the ordinary pump-logs. Examples of this kind were shown among the exhibits from Canada, portions of which Dominion are comparatively new. The records of the United States Patent Office show that improvements in pumps were numerous from the first. We observe that in 1833 Messrs. J. & J. Reed, of Plymouth, Massachusetts, took out a patent for a cast-iron pump.

The manufacture of pumps on an extended scale, as a special business, appears to have been first commenced by Messrs. W. & B. Douglas, of Middletown, Connecticut. This firm was established in 1832, and claims to have originated the principal designs for the metal domestic pumps now so generally known and used. The firm made a prominent display at the Exhibition.

The manufacture of pumps was commenced at Seneca Falls, New York, about the year 1840, by the firm of Paine & Colwell, which met with such success that two other firms soon commenced the same business. One was the well-known firm of Cowing & Co., which was succeeded in 1864 by the firm of Rumsey & Co., which made a prominent exhibit; the other, that of Downs & Co., which was succeeded by the Gould's Manufacturing Company, which also made a prominent exhibit. A similar manufacture is also conducted by the Union Manufacturing Company, of New Britain, Connecticut, which also exhibited.

The Seneca Falls manufacturers undoubtedly had much to do with the design and introduction of many of the familiar forms of pumps now so widely known, and their modern styles are on the whole superior in the beauty of the designs.

It is impossible to detail all the varieties of pumps made to suit various locations and uses. All the manufacturers exhibited pumps for ordinary wells, for deep wells, for cisterns, for use on sinks, in various forms, with spouts, and with pitcher-tops, etc., and of every variety and size. Force-pumps were shown, single- and double-acting, in equal variety. Variations were made, too, in the kind of material used; some pumps being of iron, others of brass, and others

of a combination of the two. Some of the pump-barrels were enameled, others tinned or galvanized, and a few were shown with glass cylinders, properly secured, designed to suit the particular fluid operated upon. Certain forms of pump were mounted on wheels, and in form, size, and finish made suitable for fire- or garden-engines, for raising and distributing liquid fertilizers, and like uses. The business includes large reciprocating pumps and centrifugal pumps, driven by power, and rotary pumps operated by hand or power; also, hydraulic rams, hose carriages and carts, and matters of detail in connection with the general subject too numerous to mention.

The displays of the Gould's Manufacturing Company, of Seneca Falls, New York; that of Rumsey & Co., of the same place, and that of W. & B. Douglas, of Middletown, Connecticut, were quite prominent. The firm last named appeared on the whole to show a greater variety of styles, but the Gould's Manufacturing Company had the most attractive display. The details and workmanship of the pumps exhibited by all the manufacturers were substantially the same, except that the Douglas firm simply "smooth-bore" their pump-barrels, and the other firms polish them. Messrs. Rumsey & Co. report that they annually make nearly 100,000 pumps. Several of the firms estimate the value of the pump-industry in the United States at \$1,000,000 to \$1,250,000 annually, and probably two-thirds of the business is done by the several firms at Seneca Falls, New York. The pumps are exported largely to all parts of the world where agricultural or labor-saving machinery is introduced.

There were few domestic pumps shown in the foreign departments. Mr. C. Blunck, of Norway, exhibited several varieties of pumps of this kind in connection with cocks, valves, ornamental cast-iron fonts, etc.; the exhibit being quite complete, considering the distance that it had been brought. A small, well-finished fire-engine was included in the exhibit from the Netherlands.

Messrs. Thomas Haynes & Sons, of London, England, exhibited the "Hydronette," a hand fire- and garden-engine, made with telescopic tubes in direct continuation of a length of hose; the simplicity and efficiency of which was surprising. In connection with an air-chamber, called the "Water-Bringer," water could be drawn a long distance. A very convenient hose-carriage, for garden use, was included in the exhibit.

DRIVEN WELLS.

All the pump manufacturers exhibited points for driven wells, and pumps for operating in connection with them. The driven well is

one of the most important inventions of the age, as will be seen by contrasting previous methods for obtaining water with the simple means latterly available.

Wells, which were doubtless developed by gradually deepening open pools and walling them in for protection, have in all ages been of paramount importance. In the times of the patriarchs, large districts in the East, located at a distance from natural fountains and water-courses, were made habitable only by the existence and possession of these artificial reservoirs, the construction of which in those lands, with facilities then available, was an enterprise of the greatest magnitude. Wells were then princely inheritances, and determined the locations of the feeding-grounds of the flocks, the lengths of journeys, and the sites of cities. During the thousands of years since that time, wells in other countries, if not so sacred or valuable, were still an absolute necessity, and any improvements tending to produce economy or efficiency intimately concerned all nations; yet, with the exception of artesian wells, which are of comparatively limited application and involve great cost and risk, no improvements were made, and wells to supply the every-day uses of mankind remained unchanged until the invention of the driven well, in the year 1861, by Colonel H. M. Green, then of Cortland, New York, which is now controlled by Messrs. William D. Andrews & Bro., of New York City.

The invention grew out of the exigencies of the civil war, and the want of some means to quickly procure an abundant supply of water, protected from the danger of its being poisoned by an enemy, and procurable by some device easily transported, and capable of repeated use and removal, to meet the necessities of a moving army. Previous to that time it had been considered necessary to have a reservoir of water below the earth's surface, which could be drawn upon at will, and would fill again gradually by percolation through the porous strata of the soil or cavities in the rocks. The discovery of Colonel Green was that no reservoir was necessary, but that, by creating a partial vacuum at any point in the earth below the natural water-level, water would be forced to such point by the pressure of the air in quantities unattainable by the use of a reservoir. The apparatus for utilizing the discovery consists simply of a tube driven into the ground to a sufficient depth, shod at the bottom with a perforated point, and provided at the top with an ordinary suction-pump, the operation of which creates a partial vacuum at the bottom of the pipe, and brings to the surface a copious and continuous supply of water. As is well known, it is easy to exhaust the supply in an ordinary well, and it is

evident that the time required to fill it again, or to maintain a certain level, while water is being withdrawn, as the case may be, will depend upon the velocity with which the water will percolate through the porous soil or rock down an obstructed hydraulic slope, from the natural height of the water in the vicinity to the reduced height in the well. When, however, the reservoir is dispensed with, and suction is brought upon the porous strata direct, the influence extends over a very large area, and water flows in from all directions, the small cavities or spaces between the particles of rock or soil acting as so many supply-pipes, through which water is forced by the atmospheric pressure with an intensity proportioned to the vacuum attainable. The natural head of the water in the soil above the bottom of the tube balances a corresponding head within, so that the height of lift does not depend upon the length of pipe, but upon the depth of the natural water-level below the surface, and the head upon the particular stratum reached.

The simplicity and utility of the invention led to its rapid introduction. It is estimated that there are over one million such wells in use in the United States. The well received early recognition in England and France. The English army in Abyssinia, in 1867-68, were furnished material for two hundred of these wells, of which some forty were placed permanently on the line of march, and the remainder transported with the moving army for temporary use. Their construction and care were placed in charge of Lieutenant Le Messureau, of the Royal Engineers, and a special corps of assistants, who drove the wells at each halting-place, withdrawing and removing them whenever the march was resumed. Thus, in the very land where Bruce records that he obtained water from the stomachs of camels, which his companions had slain for the purpose, large armies afterwards marched in safety. Full particulars of the adoption and use of driven wells by the army in Abyssinia are to be found in the reports of Sir Robert Napier, transmitted to the British Parliament and published in their proceedings. In these reports proper credit is accorded to them as an American invention, and their uses and advantages are set forth, and the statement made that by the opportune arrival at Magdala, on pack-mules, of material for two of the wells, pure water was furnished the forces after an enforced abstinence of sixty hours' duration.

Mr. S. K. Morrison, of Melbourne, Australia, exhibited in Agricultural Hall apparatus referred to as "Patented Abyssinian Tube Wells and Pumps, with Boring Apparatus," which was evidently a reproduction of the American types furnished for that campaign.

At about the time driven wells were used in Abyssinia the Emperor of the French personally superintended their experimental operation at Buchy, and near Paris, under the direction of the American agents, which met with such decided success that a number were ordered for the army and for the School of Agriculture. These wells are adapted to supply water to households, farms, and manufactures, and for armies in camp or on the march, emigrants journeying overland, miners, explorers, lumbermen, hunters, etc., and furnish ready means for procuring water in most localities where it would otherwise be practically inaccessible.

Water is procured from the sand and gravel strata of the soil, and in many localities one or more layers of clay are passed through before the most desirable quality of water is reached. The depth is to a great extent governed by the quantity, quality, and temperature required, and varies from 30 to 100 feet. The deepest wells furnish the coolest water, and intermediate ones a different quality. Water is usually found from 10 to 25 feet below the surface, but a majority of wells are over 40 feet deep, and in all cases the water rises to a level with the surface water.

For manufacturing purposes, where large quantities of water are required, a number of two-inch tubes (the usual size) are connected to one larger main pipe, to which a steam-pump is attached. From two to twenty tubes have been so connected. The tubes are driven by a falling weight, like a pile-driver, weighing from 50 to 150 pounds.

Some trouble was at one time experienced by the points becoming corroded and stopping the inlet passages, in which case it was necessary only to withdraw the tubes, attach new points, and replace tubes; but with the points now used such stoppages do not occur, and wells in use for several years furnish water as freely as when first driven.

Driven wells are being largely introduced even in the cities of New York and Brooklyn, where the best improved modern systems of water-supply are in use, and have superseded dug wells and cisterns, the result being a saving in cost of the water used that is truly remarkable. Driven wells are in constant operation on the premises of the Western Union Telegraph Company, Whiting Manufacturing Company, Matthew White Malt-House, in a large number of breweries, in the New York *Herald* and other newspaper establishments, in Hecker's Flouring-Mills, in the Manhattan and a number of other sugar-refineries; also in chemical works, mineral water establishments, and a large number of other manufactories. It appears from testimony in a United States court that the New York Gas-Light Com-

pany are making a saving of \$8000 per year in cost of Croton water alone by the use of two gangs of these pumps at the works at the foot of East 21st Street. The low temperature is also of great advantage in washing gas and cooling coke. In Brooklyn driven wells are also largely introduced in various manufactories.

The soil underlying the city of New York consists generally of strata of sand, loam, gravel, and an exceedingly tenacious clay. These layers also vary in thickness and order in different places, there being from one to three layers of clay each from 6 to 14 feet thick in the depth of 100 feet. In Brooklyn, in one instance, on Imlay Street, a depth of 100 feet of clay was passed through, when beneath a good supply was reached which rose to within 8 feet of the surface.

Most of the wells mentioned are used steadily ten hours per day, some for twenty-four hours each day, for six days in the week, while others are in constant operation,—and after months, and in some cases years of use, the supply continues undiminished.

The reliability of driven wells for continuous supply has led to their extensive adoption by villages and small cities for fire purposes, etc., and it is possible that some of the larger cities may find it advantageous to utilize this cheap and efficient means of increasing their water-supply, and save the expense of extending their aqueduct and reservoir systems.

The driven well, in all places where it is applicable, will probably supersede the old methods of well-making, for in addition to its simplicity and convenience, it avoids the necessity of using surface water, the contaminations of drainage, vermin, etc., to which open wells are subject, and draws its supplies from either of the cooler and purer strata usually found deeper in the earth, each having distinctive qualities, and from which any desired selection may be made, and the others excluded.

HYDRAULIC PRESSES.

M. Morane, Jr., Paris, France, exhibited a horizontal hydraulic press for use in the manufacture of candles. The material to be operated upon was to be placed in the press in bags, which were arranged between plates heated by steam introduced through telescopic tubes. A small hydraulic ram was provided to retract the main ram. All the parts, including the accompanying pumps, were well designed and carefully constructed.

Messrs. John Robertson & Co., Brooklyn, N. Y., exhibited a medium-sized, excellently-finished hydraulic press, with pumps, contain-

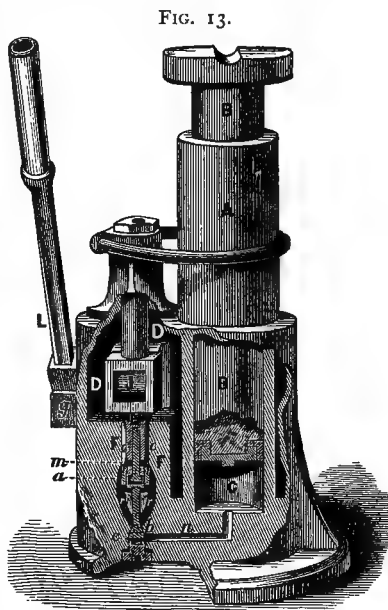
ing some improvements to insure the efficiency of the various details, which could be explained only in connection with elaborate drawings.

Mr. John F. Taylor, Charleston, South Carolina, exhibited a combined steam and hydraulic cotton-press. The upper platen was stationary, and supported two hydraulic cylinders, each about 22 inches in diameter, which operated the bed through four heavy wrought-iron bars each about 7 inches square. Water under pressure was supplied by two pump-plungers of different sizes connected directly to inclined steam-cylinders also of different sizes. In operation the pressure was first applied by means of the larger pump-plunger, which was operated by the piston of the smaller cylinder, after which the steam was exhausted from this cylinder to the larger one operating the smaller plunger. The pressure in the latter cylinder was supplemented with live steam when necessary. These presses are used in re-pressing cotton so as to enable it to be stored economically on board vessels, and are in successful and efficient operation in various Southern cities.

Messrs. Bolen, Crane, & Co., Newark, New Jersey, exhibited hydraulic presses in which water was admitted under pressure to canvas rubber-coated bags located between stationary and movable plates, arranged alternately one above another. The stationary plates are connected by side rods to a cross-head at the top, carrying a large adjusting-screw, and the movable plates are connected by studs, so that all act at the same time on the bed-plate. The bags are connected together for the passage of fluid through a pipe formed by compressing studs on external ears. The bags are made by coating heavy canvas with rubber $\frac{1}{8}$ inch thick, and compressing two pieces of the canvas with the rubber faces together between two frames of iron made entirely without finish, and held together by small bolts. The bags yield sufficiently under a pressure of 50 pounds per square inch to elevate the bed two or three inches. The bags last about a year and cost but little to renew. The largest press in use contains 10 bags, each 20 inches by 20 inches, and yields a total pressure of 100 tons, with a water pressure of but 50 pounds per square inch. The pressure from city water-works is ordinarily sufficient, but may be supplemented by using an ordinary force-pump.

HYDRAULIC JACKS.

Hydraulic jacks were shown by four exhibitors, the principal exhibit being that of the original inventor of these useful tools, Mr. Richard Dudgeon, of New York. The Dudgeon jack was invented in 1848, and its development at that time involved inconceivable difficulties on account of getting suitable tubes, etc. The usual difficulties were also encountered in its introduction, after which it came into very general use. The later form of the Dudgeon jack is shown in Fig. 13. The supply-chamber is at D; the receiving-valve of the pump is in the lower end of the plunger E; the fluid being supplied by grooves in plunger communicating with a cross-opening. The delivery-valve of the pump is located in an inverted position at the bottom, and supported by a spring. To lower the jack the operating handle is reversed, and is so shaped that it will then force the pump-plunger



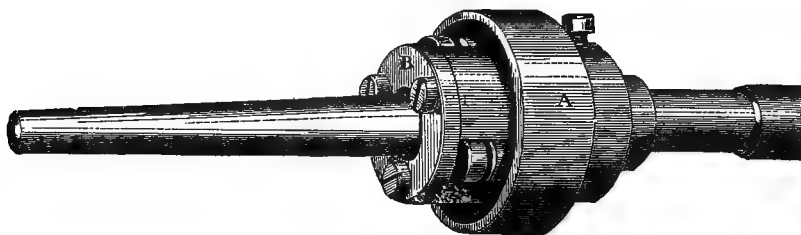
R. Dudgeon, Hydraulic Jack.

lower than the usual position, open by contact the delivery-valve at the bottom, and at the same time expose in pump-chamber the cross-opening in plunger, previously mentioned, and thereby give the fluid an opportunity to return to the supply-chamber D. The exhibit included several forms of the hydraulic jack adapted to various uses, among others a pulling-jack. Specimens of the Dudgeon hydraulic punch were also shown. It much resembles an ordinary screw punch in size and appearance, but the punch proper is carried by a plunger which is separated from the end of the screw above by a fluid. The screw is effectually packed on the threads, thus forming the pump of a small hydraulic press of great power and remarkable compactness.

Mr. Dudgeon also exhibited his boiler-tube expanding tool, invented in 1867, and now very extensively used. For convenience it is illustrated in this connection, in Fig. 14, though not a hydraulic exhibit. A hollow cylinder B, of less diameter than the boiler-tube, and provided with a guide-sleeve A, to bear against the tube-sheet, is pro-

vided with openings to receive small grooved rollers which rest inside on a central conical mandrel. By inserting the tool into the tube and pressing upon and revolving the mandrel, the rollers expand the

FIG. 14.



R. Dudgeon, Boiler Tube Expander.

tube in the sheet with great facility ; the instrument being, in fact, so powerful that care must be employed in its use, and it is not uncommon to see the tube openings themselves expanded by the pressure applied inside the tube.

WATER MOTORS.

The exhibit of turbines was quite large. The desire of the Group to have them thoroughly tested, by utilizing the large elevated tank of the waterfall in connection with the flume provided for in the plans of the Bureau of Machinery, could not be carried into execution while the co-operation of the foreign members was available. At a late date, however, when, in the opinion of Prof. Reuleaux and others, it was not practicable to make thorough tests in the time available, an arrangement was completed in the Bureau of Machinery to make a series of tests at the expense of the exhibitors, under the charge of Mr. Samuel Webber, a member of another group, whose engagements permitted him to devote his time to the subject. Group XX. co-operated by inviting Mr. Webber to become an associate member ; the tests were proceeded with, and, by strenuous efforts, in which two sons of Mr. Webber rendered valuable services, a series of experiments was completed, which appear in the report of Mr. Webber to the Bureau of Machinery, hereto appended, the illustrations in which show fairly the construction of the several turbines.

The experiments served fully the purpose of ascertaining the relative performances of the turbines when tested under similar conditions, but, unfortunately, do not fully answer the original purpose of the

Group to obtain results with the great accuracy required in correcting the constants and extending the formula applicable to the subject. Carefully-conducted experiments with turbines then in use are described in the well-known work on Hydraulic Experiments, by Mr. James B. Francis, of Lowell, Massachusetts. His formula for the flow of water in rectangular weirs, based on elaborate trials, has been shown by Prof. James Thomson to correspond in form with that determined mathematically, and, from the care and discrimination exercised in the various experiments, the methods and deductions have been accepted as a standard.

The brake used at Philadelphia for measuring the power was similar to that employed by Mr. Francis, and operated with perfect satisfaction. A question arises, however, as to the absolute accuracy of the water measurement, as, in the haste to complete the work, precautions observed in the more prominent experiments on the subject were neglected. The water was necessarily admitted to the side of the weir approach, and proper measures were not taken to remove eddies and secure uniform velocity in the direction of the weir, or to protect the openings to the hook gauge-box from the influence of the maximum current. The initial and final curves, angles, areas, etc., of the wheels and of their supply openings were ascertained for most of the turbines, and part of the information is embodied in Mr. Webber's report. The templates of the angles and curves, in the possession of the writer, are available for discussion when the influences on the results, due to variations from the standard method of the nature referred to, shall be settled by experiments on the subject.

The experiments show that turbines are now so perfected as to give the highest efficiency of any hydraulic machine. Mr. Uriah Boyden, of Boston, Massachusetts, is believed to be the first person in the United States who devoted his energies to the improvement of turbines, and his success gave an impetus to investigation and invention on the subject. The results obtained with the Boyden-Fourneyron turbines have never been equaled. Turbines of this kind are now designed and constructed by Mr. Edward Sawyer, of Boston, Massachusetts, who exhibited drawings of them in the rooms of the American Society of Civil Engineers.

The only turbines exhibited from abroad were in the Canadian Department, some of which were tested, as is shown in the report. Drawings of double turbines, ingeniously arranged, were shown by Mr. A. J. Atterberg, of Hagforsen, Rada, Sweden. Mr. W. Wenström, of Orebro, Sweden, exhibited drawings of a water motor of a type discussed in theoretical works, but not yet introduced in the United

States. The construction resembles an undershot-wheel adapted to be run under water, if necessary, like an ordinary turbine. The water is admitted through a scroll-shaped conduit partially surrounding the wheel, and, entering a certain distance between the vanes, which are turned towards the current, it is finally thrown out by centrifugal force, and escapes through an opening in the case beyond the supply passage,—the path taken by each particle of water resembling two branches of a cycloid. The construction readily admits the location of several wheels, of the same or different widths, on the same shaft, to suit variations of power.

MISCELLANEOUS.

The exhibits of pipes, stop-valves, cocks, beer-engines, soda-water machines, bottling-apparatus, corking-machines, etc., referred to this Group, were all very complete, but involve too much detail to admit of description. The advances made in the manufacture of wrought-iron and brass pipe were quite conspicuous. The National Tube-Works, of Boston, Massachusetts, and McKeesport, Pennsylvania, was the first firm in this country to engage in the manufacture of exceptionally large wrought-iron seamless pipes. The firm exhibited wrought-iron pipes of various sizes, from $\frac{1}{8}$ inch to 15 inches in diameter, both thin and thick. At the date of writing, still larger sizes are made by the firm mentioned, and by Messrs. Morris, Tasker, & Co., the well-known manufacturers of Philadelphia, Pennsylvania, and New Castle, Delaware, who had also a very creditable and prominent exhibit.

BLOWING MACHINERY.

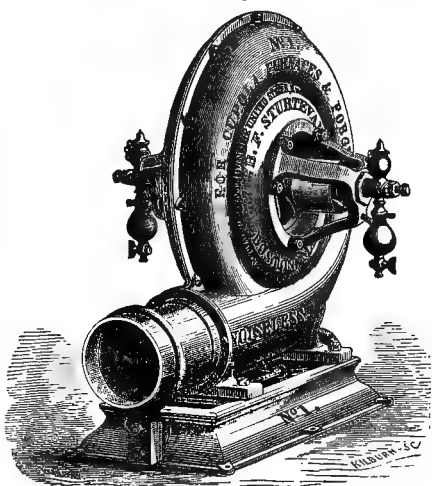
The principal exhibit of fan-blowers, exhaust-fans, etc., was that of Mr. B. F. Sturtevant, of Boston, Massachusetts. This manufacturer has made a special study of the mechanical details of blowers, and has systematically conducted a large number of experiments to determine the best proportions for delivering a desired volume at a given pressure, with maximum economy. His illustrated albums are of considerable interest and value independent of the purpose for which they were designed. Blowers of different proportions are furnished for pressure and volume. The vanes of the fan-wheels are inclined backward, and are secured between cone-shaped disks attached by light braced arms to a steel axle, the journals of which swivel in

the supporting brackets, and are provided with approved oiling attachments. The improvements, being chiefly in proportions and matters of detail, would require elaborate drawings for illustration. The exterior view (Fig. 15) will serve to illustrate the taste exhibited in the designs.

A very creditable exhibit of fan-blowers and exhaust-fans was also made by the Exeter Machine-Works, of Boston, Massachusetts.

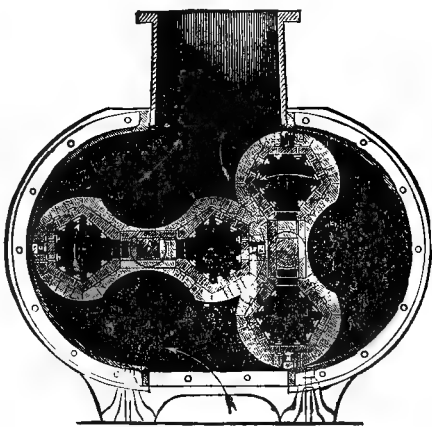
The two principal exhibits of rotary blowers and exhausters were those of Messrs. P. H. & F. M. Roots, of Connersville, Pennsylvania, and of Messrs. Wilbraham Bros., Philadelphia, Pennsylvania. An ordinary form of the largest sizes of the Roots blower is shown in Fig. 16, from which the operation may be readily understood. The peculiarity is in the shape of the rotary pistons,—all outlines of which are arcs of circles. For each piston a suitable metal centre is secured to the shaft, and is covered with wood, which is readily put in the shape desired. The relative positions of the pistons are maintained by external gearing, which is provided with safety casings. For small-sized blowers, as well as for exhausters, which latter require greater accuracy in fitting, the rotary pistons are constructed of metal and accurately fitted to the shape shown in Fig. 17. Suitable adjusting pieces are also provided in the exhausters, by which any reasonable degree of tightness may be obtained. For smaller blowers the pistons are carefully fitted, and the cases provided with recesses, which are

FIG. 15.



B. F. Sturtevant, Fan Blower.

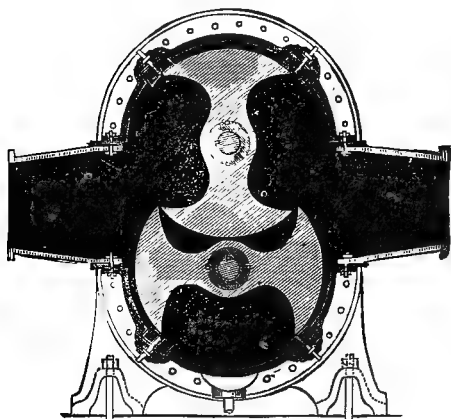
FIG. 16.



Roots Blower.

filled with a composition containing plaster of Paris, which insures tightness at a reduced expense. Messrs. Wilbraham Bros., above

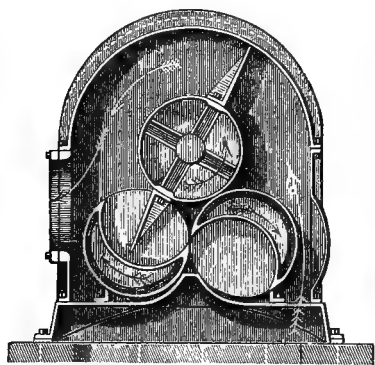
FIG. 17.



Roots Gas-Exhauster.

mentioned, manufacture the Baker rotary blower, of which a sectional view is shown in Fig. 18. The same arrangement is used as an exhauster and as a pump for fluids. In a case of the shape shown, a

FIG. 18.

Baker Blower, Wilbraham Bros.,
Philadelphia.

central finished drum is provided with two vanes or rotary pistons, fitting fairly the two ends of the case and the bored semi-cylindrical top. In the bottom are two drums, which run closely together and to the central drum, and to the former motion is im-

parted opposite that of the latter, and with double its velocity, by external gears (encased to prevent accident). The lower drums are crescent-shaped, as shown, the exteriors being turned and running close to projections on the case. In operation, as each vane of the central drum passes from right to left, air is received at the bottom of the right-hand side of the case, which is forced out of the opening at the left. The opposite vane moves through the opening in each of the lower drums successively, and the latter turn so as alternately to form abutments to prevent escape from the delivery side at the left to the receiving side at the right. The cavities in lower drums are kept free of the vanes, so all necessary

fitting can be performed in a lathe. These blowers are run at pressures varying from a few ounces to three pounds per square inch, and have been successfully applied to a large number of purposes, but principally for smelting-furnaces and smitheries.

There were two prominent exhibits of blowing-engines for blast-furnaces. Messrs. I. P. Morris & Co., of Philadelphia, Pennsylvania,

exhibited one of the type most in favor in the United States, provided with a steam-cylinder 48 inches in diameter and a blowing-cylinder 75 inches in diameter, the stroke being 6 feet. The average speed of the engine does not exceed 20 revolutions per minute, and the usual blast pressure is 10 pounds. The cylinders are arranged vertically with the blast-cylinder above the other. The main shaft crosses underneath the main cylinder, and carries at each side heavy fly-wheels, acting also as counter-balance wheels, to which are attached the crank-pins. From the latter connecting-rods are extended upward to a cross-head, attached to the piston-rods between the two cylinders. Steam is distributed by single poppet-valves, each of which is constructed with a cylinder on its top running freely over a stationary piston. In operation each valve-stem first lifts a "pilot" valve, or small valve seated in the top of the main valve, which equilibrates the pressure between the lower side of the main valve and the piston above it, when the pilot-valve comes in contact with the main valve and lifts it quite easily. This arrangement, designed by Mr. A. Wanich, secures the tightness of a single poppet-valve with the ease of operation due to a balanced valve. The engine was very well constructed, and the design and details were carefully worked out.

Mr. P. L. Weimer, of the Weimer Machine-Works, Lebanon, Pennsylvania, exhibited a high-speed blowing-engine, with steam- and air-cylinders respectively 20 and 50 inches in diameter, the stroke being 24 inches. The engine was designed to run regularly at a speed from 75 to 100 revolutions per minute, and had been run on trial at 136 revolutions per minute. The general arrangement of steam-cylinders and connections was the same as that of the engine previously described. Steam was distributed by a slide-valve operated by a link motion. The principal feature of novelty was the design and arrangement of valves in the blast-cylinder. Many persons after watching for a time the slow movements of a large blowing-engine of the ordinary type, have expressed surprise that an engine had not been constructed to perform the same work with equal reliability at higher speeds, as similar changes have been successfully accomplished with engines designed to perform other duties. For instance, slow rolling-mill engines of the past have been superseded by smaller ones directly connected to run at the full speed of the rolls, and paddle-wheel engines on ocean steamers have been replaced by quicker-acting screw-engines. The difficulty in designing a high speed blowing-engine is to obtain sufficient valve area to admit the air without increasing the waste space so as to produce serious loss of action, which has been successfully overcome by Mr. Weimer in the manner

FIG. 20.

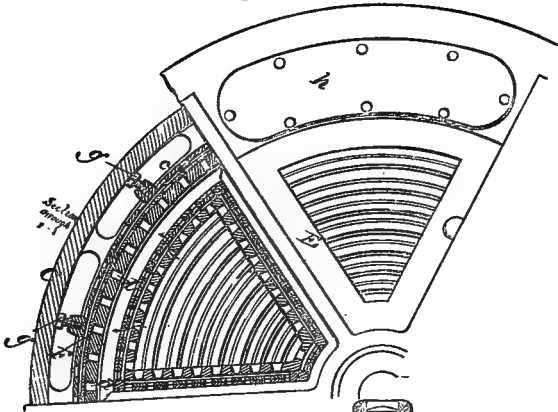


FIG. 21.

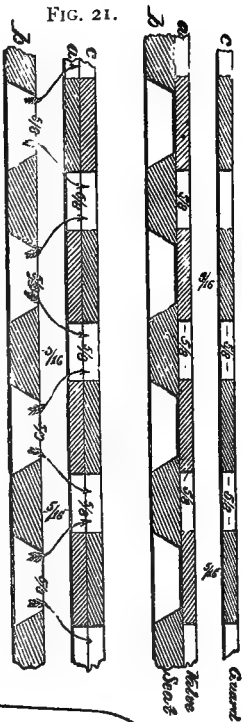
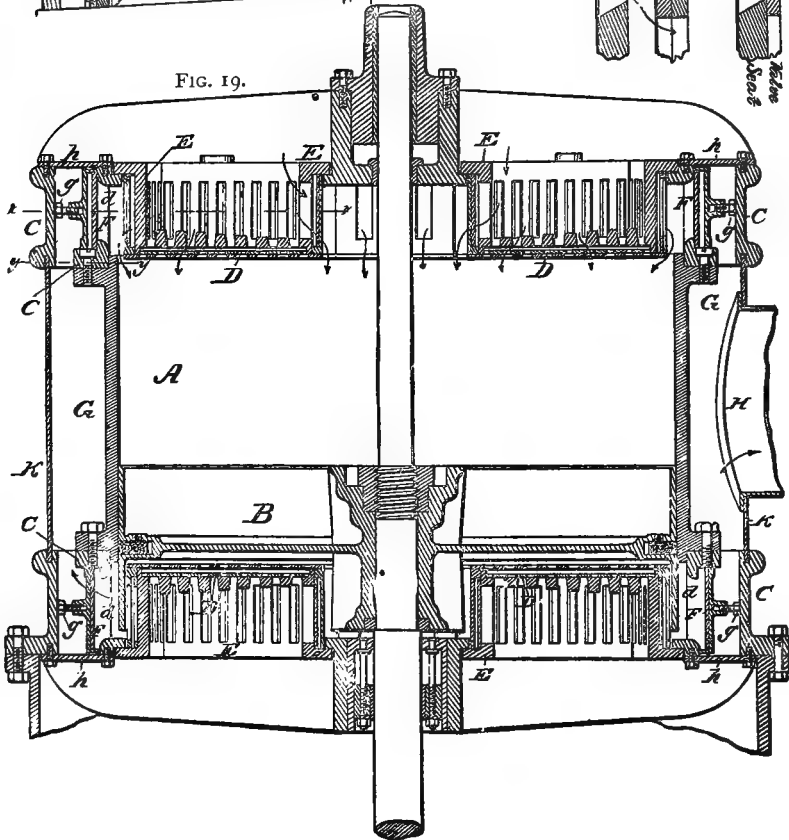


FIG. 19.



P. L. WEIMER, CYLINDER AND VALVES OF HIGH-SPEED BLOWING-ENGINE.

illustrated in Figs. 19, 20, and 21. To the ends of the blast-cylinder are attached annular chambers, C, containing inside the inner shell the delivery-valves, which chambers are connected by a casing or jacket forming the delivery-chamber, from which the compressed air is conducted by suitable pipes. Into each end of the cylinder, lengthened by the chamber mentioned, are extended sectors, open at their tops and provided with gratings in their bottoms and sides, the outer diameter of the sectors being a little less than that of the bore of the cylinder. The sectors are connected together at their outer ends, and form the cylinder cover. The openings in the bottoms of the sectors are concentric with the cylinder; those in the sides are arranged vertically, and all have usually a width of $\frac{5}{8}$ of an inch. Each grating is covered inside the cylinder by a gridiron-valve made of a single thickness of leather, which operates between the grating or valve-seat and a guard perforated to correspond with the valve, the distance between the guard and valve-seat being adjusted to give about $\frac{5}{16}$ of an inch lift (see Fig. 21). The delivery-valves are similarly constructed, being made in short sections and inserted through openings covered by bonnets, *h*. By this means all the area necessary for the admission of air at high speeds is obtained. The piston, B, is made with a central disk, provided on either side with cylindrical flanges stiffened by ribs. The ribs, the external flange, and the central boss run into the space between and around the sectors, and reduce the clearance and waste spaces to a minimum. The piston packing is of wood, set out with springs. When engines of this class are run rapidly the compression of the air serves to cushion the reciprocating parts, for which reason the manufacturer expects to obtain higher speeds than are common with other engines.

TRANSMISSION OF POWER.

One of the most instructive exhibits to foreign engineers was the system of transmission of motion in Machinery Hall, and in the various other buildings in which machines in motion were exhibited. The few examples of the American system of transmission at Paris and Vienna in 1867 and 1873, and the subsequent comments in the various foreign journals, had prepared the experts who visited America in 1876 to note carefully the system, as a whole, and its operation, as here for the first time it had been displayed in its fullness at a world's fair. The importance of this branch of engineering calls for a brief historical sketch, and some little explanation of the principles involved. A recent writer on the subject says, "In any large factory

the shafting, with its couplings, pulleys, and other adjuncts, considered as a machine to transmit motion, is most frequently the largest in the establishment; hence every consideration of economy requires that it should do its allotted work with the least possible loss of power in the transmission. It calls for economy in first cost, and economy in use."

The first distinctive feature of the American system is the extended use of belting in place of toothed gear-wheels to transmit motion from the motor to the various lines of shafts, and thence to the machines. In 1841, Prof. Willis, in his *Principles of Mechanism*, says that in London belts were much used on account of their silent and quiet action, but that in American factories their use had greatly extended. "In Great Britain the motion is conveyed from the first moving power to the different buildings and apartments of a factory, by means of long shafts and toothed wheels, but in America by large belts moving rapidly, of the width of 12 or 15 inches, according to the force they have to exert." This really sounds the key-note to the American system, which has extended to the almost entire abolition of toothed wheels for transmission except at low speeds and on the ground-floor, and the substitution of belts of even in many cases four feet in width; one belt exhibited, and hereafter referred to, was five feet in width. That the subject of toothed wheel transmission has not been neglected in this general preference for belts was pleasingly illustrated by Mr. Corliss, who furnished the shafts and bevel-wheels which transmitted the motion of his large engine to the various points from which the belts took it to the line shafts. The construction of the bevel-wheels, planed true on each tooth by his planing-gear-cutter, the firmness and rigidity of their ground fastenings, coupled with their high speed for gearing of that kind, furnished a notable example of the most approved gear-wheel transmission on a large scale,—working so well and silently as to be unknown to many who walked daily over the floor that concealed them, and familiar only to those who traced out the system from the engine. The line shafting running in bearings attached to the beams overhead was at all times in full sight, and could not fail to attract attention from its extent and smooth running. This part of the exhibit was American in every particular. In Machinery Hall there were eight main lines of shafting; the largest diameter being 6 inches at the head-shafts, and decreasing to 3 inches as the smallest diameter, the total length of each line being about 623 feet. The shafting erected by Messrs. William Sellers & Co., of Philadelphia, formed much the largest part of the entire exhibit in Machinery Hall, inasmuch as they shafted the half

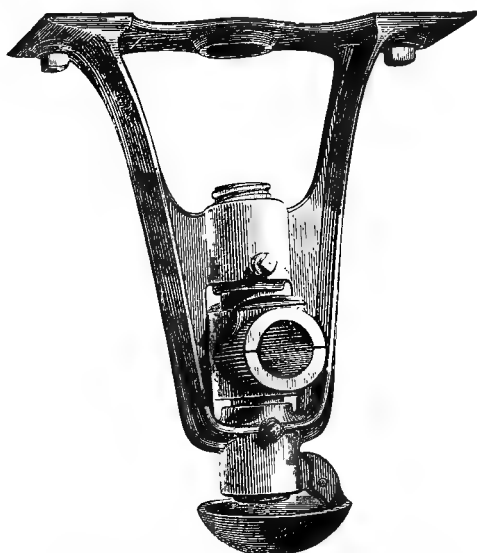
of the main room east of the transept. They also erected the shafting in Brewers' Hall, and put up many of the private lines, in all furnishing about 3500 feet. When bids were asked for by the Board of Finance for this work, that of William Sellers & Co. was the lowest, but as other makers of shafting desired space to exhibit lines in motion in Machinery Hall, they relinquished one-half of this building to them. All the shafts were of wrought-iron,—each line of 623 feet being collared at one end only, and held so securely by couplings as to be practically, as far as strength was concerned, an unbroken bar of that length. The couplings used were of the adjustable kinds, and the hangers of the ball-and-socket pattern. The speed of all lines used to drive iron-working machines and the like was 120 revolutions per minute, while that of those driving wood-working machines was 240 revolutions.

The American preference for high-speeded belted shafts has been the growth of years. In mills built thirty years ago, examples of toothed wheel transmission, so generally employed in Great Britain, were common, but belted mills were growing in favor. Since then many of the former have been remodeled on the new plan. The essential features of American shafting, as a piece of mechanism in its entirety, originated with the house of William Sellers & Co., who were the first persons to engage in it as a distinct branch of manufacture, and to establish a fixed scale of prices for each and all of the various items which go to make up the transmissive equipment of any establishment. This scale of prices was brought about by the introduction of the first really practicable adjustable coupling, which enabled them to abandon the hook or open-sided hanger, in use with the plate-coupling, for a lighter but stronger form of double-braced hanger.

To Mr. Edward Bancroft, the former senior partner of the present house of William Sellers & Co., is due the introduction of the swivel principle of box or bearing in line-hangers. Later, his improved ball-and-socket hanger took its place, to which was added the principle of adjustment for alignment. (See Fig. 22.) This form of hanger was a marked improvement, and has now come into general use. The spherical supports of the long bearing insure absolute uniformity of pressure over the lubricated surface, and diminish the frictional resistance. Added to this, a matter of no little moment, the cost of erection is reduced to a minimum,—there being no necessity of any special care in setting the feet of the hangers, as all required adjustments to line are either possible or self-controlled. This principle of hanger with well-fitted plate-coupling contributed to make up

the best type of shafting, apart from considerations of first cost and ease of repairs afterwards. The plate-coupling (see Figs. 23 and 24)

FIG. 22.



Ball-and-Socket Hanger, William Sellers & Co.

FIG. 23.

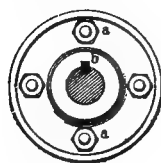


FIG. 24.

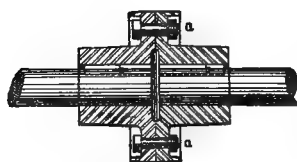
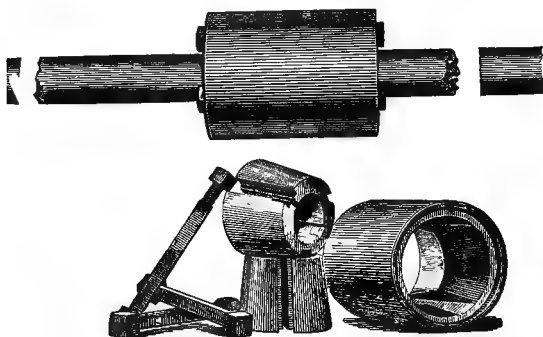


Plate-Coupling.

required that each half be securely fitted to the end of the shaft to which it belonged, that the pairs, to be afterwards bolted together, be true with the axis of the shaft, and this accuracy was represented in the first cost of the work. Couplings of this kind were fitted with care, and then fixed in place with powerful screw-presses, rendering the attachment of pulleys expensive and troublesome. Their use also involved the use of the open-sided hook hangers in place of the double-braced hangers, previously referred to. Attempts had been made to use sleeve-couplings, but in 1856, William Sellers & Co. introduced what they call their "double cone vice-coupling," shown in Fig. 25. This holds the shaft centrally within an external sleeve, regardless of slight differences in the size of shafts, and as the clamping cones within the outer sleeve are drawn towards each other by the through bolts, a uniformity of pressure is obtained on each shaft end. The use of this coupling did away entirely with the expensive fitting necessary in the use of the plate-coupling, and rendered possible the production of standard shafts of given lengths, splined on the ends for keys, but requiring no special care in the accuracy of size at the ends; and the introduction of this coupling, and the improvement in the form of the ball-and-socket hanger,

already alluded to, rendered possible for the first time the manufacture of shafting with interchangeable parts, and the production of a price-list for these parts, in place of the old plan of selling all

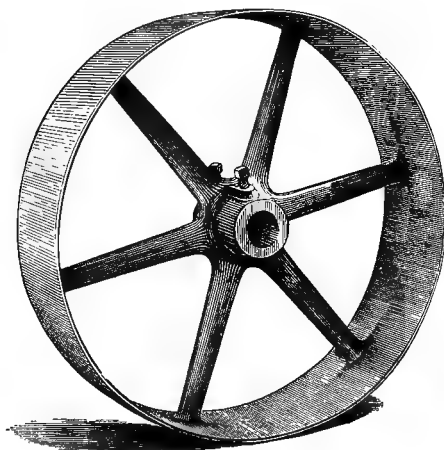
FIG. 25.



Double Cone Vice-Coupling, William Sellers & Co.

such work by the pound. This was immediately followed by an extensive series of experiments on the proper proportions of pulleys or band-wheels for the various uses to which they are applied, and the remodeling of all the minor accessories of shafting, to admit of

FIG. 26.



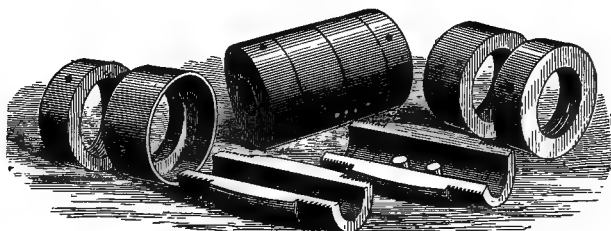
Pulley, William Sellers & Co.

graded prices per piece. Under the old system, or want of system, the purchaser was ignorant of the total cost until the completion of the work; whereas under the new system it is always possible to

ascertain the cost before the order is given to execute the work. The pulleys made by William Sellers & Co. have always been with straight arms (see Fig. 26), instead of the crooked or S arms still in use by many makers. It is claimed that the straight-armed pulleys can be made with the least possible metal to obtain a given strength, that they are best suited to transmit the peculiar strains brought to bear upon them, and are at the same time pleasing to the eye. The rapid growth of manufactories in America during the past quarter of a century has developed a great market for shafting, while improvements in methods have reduced the cost to the consumer. It is not possible to arrive at a correct estimate of the amount of shafting made in the country, but we are informed that, during years of business prosperity, the newly-erected cotton- and woolen-mills alone necessitated so large a production that often the firm of William Sellers & Co. had as much as 10 miles of shafting under construction at one time. Their market is now extending over a large part of the world, and their models have not only been introduced into the leading technical schools of Europe, but have been freely copied at home.

Messrs. Jones & Laughlins, of the American Iron Works, Pittsburgh, Pennsylvania, included in their extensive exhibit cold-rolled shafting, couplings, hangers, pulleys, etc. This firm uses the Collins patent coupling, illustrated in Fig. 27. A central sleeve made in

FIG. 27.



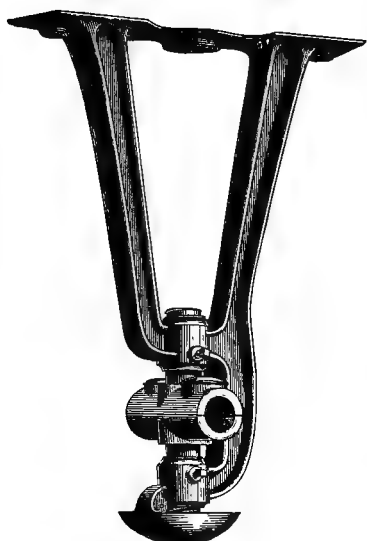
Collins Shaft Coupling, Jones & Laughlins.

halves is bored slightly less than the diameter of the shaft, and coned externally in opposite directions at the centre, over which rings, correspondingly coned internally, are fitted and set up by nuts on the ends of the sleeve, thereby maintaining the connected shafts rigidly in line. This coupling may be erected with great facility, and is readily taken apart to permit changes of pulleys, etc. The hangers employed have a long journal to receive the shaft, and the boxes at the top and bottom have spherical bosses turned upon them, to which are fitted the ends of large adjusting-screws, as shown in

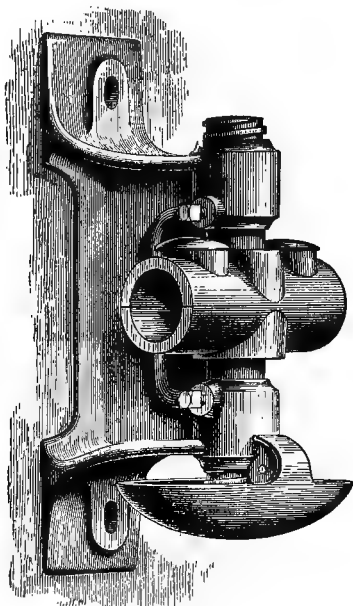
the illustration of a drop-hanger, Fig. 28, and of a post-hanger, Fig. 29. Fig. 30 represents a pillow-block, with self-adjusting bearing, set

FIG. 28.

FIG. 29.



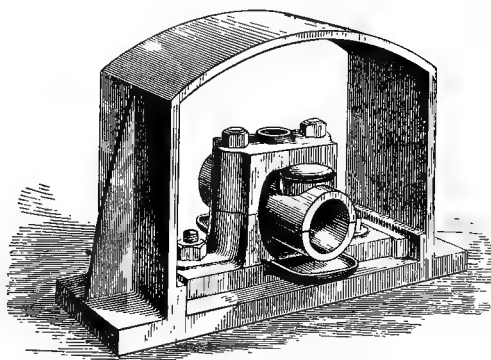
Drop-Hanger, Jones & Laughlins.



Post-Hanger, Jones & Laughlins.

inside a casting adapted to be built in a wall. Fig. 31 represents a wide-faced pulley with double arms. A pulley cast in halves, secured

FIG. 30.

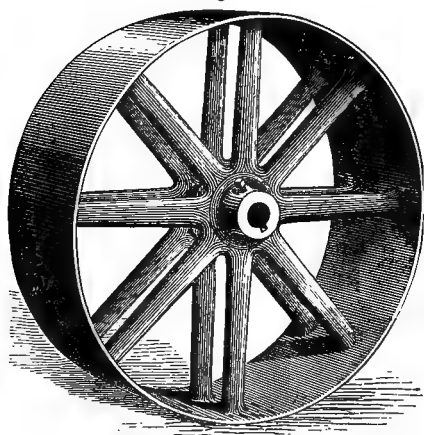


Pillow-Block, with self-adjusting bearing, in wall frame, Jones & Laughlins.

together by flanges, is represented in Fig. 32. This engraving has been selected from the cuts of the firm to show the method adopted

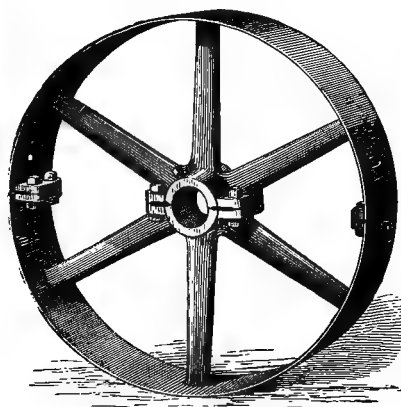
by all manufacturers in constructing pulleys for shafting not provided with adjustable couplings, or carrying so many pulleys that it is not desirable to take down the section.

FIG. 31.



Pulley with double arms, Jones & Laughlins.

FIG. 32.



Pulley, in halves.

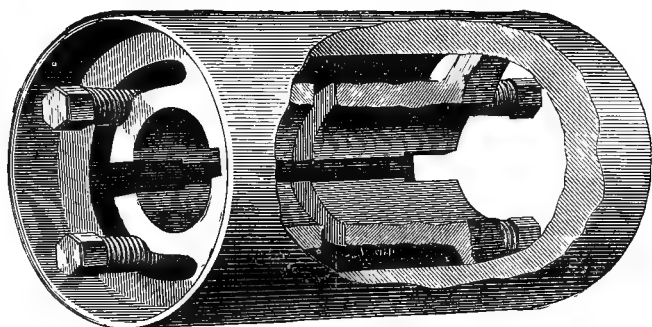
The cold-rolled shafting exhibited has a highly-polished surface, and is remarkably straight and uniform in size. The cold rolling condenses the metal, and appears to increase the strength in every essential particular. From tests made by Major Wade, of the United States Ordnance Department, in 1860, it appears that similar bars of puddled and charcoal bloom iron, all rolled hot in the process of manufacture, were increased in strength by cold rolling by Lauth's patent process, under test with various kinds of strain, as follows: Transverse strain for permanent set, increase in strength $162\frac{1}{2}$ per cent.; torsional strain to produce permanent set, increase 130 per cent.; compressional strains to produce permanent set, for test piece with length of 11 diameters, increase 64 per cent.; for length of $2\frac{1}{4}$ diameters, increase $161\frac{1}{2}$ per cent.; tensional strains to produce permanent set, increase 95 per cent.; ultimate strength under tension, increase 72 per cent.; hardness, increase 50 per cent. Sir William Fairbairn found an increase of $50\frac{1}{2}$ per cent., comparing ordinary bars of given size with similar bars reduced in size by cold rolling. A similar series of trials made by the Franklin Institute, Philadelphia, showed an increase of ultimate strength for the cold-rolled shafting of 61 per cent. in tension, and 97 per cent. in compression. The manufacturers claim that cold-rolled shafting has 75 per cent. more effective strength than the same sizes of turned iron, and

report that they had about 4300 lineal feet in motion at the Exhibition.

The cold-rolled shafting is used by locomotive and other engine builders, and by pump manufacturers for piston-rods, pump-plungers, etc., without turning, except to make connections. It is also used to make pins for bridges. Cold-rolled iron is also used in preference to steel for the finger-bar and knife-backs of reapers and mowers, and for other special purposes. Messrs. Jones & Laughlins report an annual production of 4000 tons of cold-rolled shafting, and 1000 tons of the special shapes last above mentioned.

Mr. George V. Cresson, of the Philadelphia Shafting-Works, had an extensive exhibit of shafting, pulleys and hangers, which were arranged in a novel and effective manner. The principal peculiarity in construction was the coupling, illustrated in Fig. 33. This coupling is cast

FIG. 33.



Internal Clamp Coupling, Geo. V. Cresson.

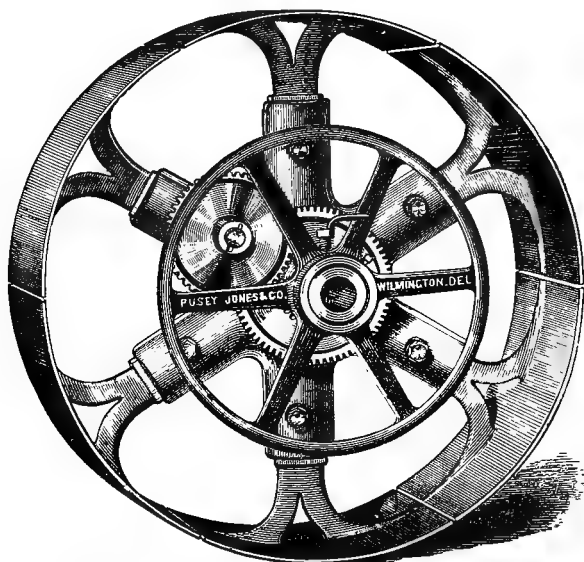
in one piece, provided with an annular recess, which, in connection with a longitudinal slit shown, forms two internal clamps at each end, which are set out against the shaft either by longitudinal tapering screws as shown, or, when the coupling is applied to a pulley hub, by set-screws arranged radially. The clamps are also divided by a transverse slit into two parts, so that each end of the shaft is grasped separately, permitting reasonable variations in size. The operation of this simple device will be readily understood without further description.

Messrs. Pool, Hunt, & Co. had also a very creditable exhibit of shafting and pulleys, the castings of the larger pulleys being particularly smooth and regular.

Messrs. Pusey, Jones, & Co., of Wilmington, Delaware, included in an interesting exhibit, relating to steam and paper-mill machinery, the

expanding pulley, of which an external view is shown in Fig. 34. The several arms carry separate segments of the rim, and are shifted radially in suitable guide-sockets in the hub by radial screws pro-

FIG. 34.



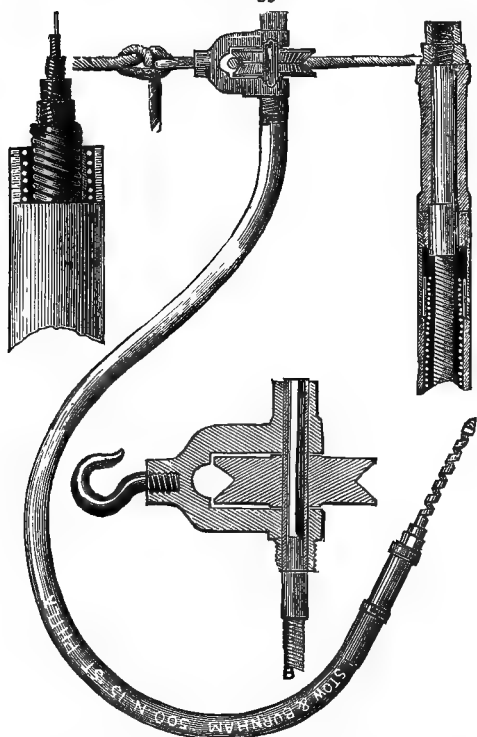
Expanding Pulley, Pusey, Jones, & Co., Wilmington, Del.

vided with bevel-gear connections to the train of gear and the hand-wheel shown. These pulleys are principally used for driving the drying cylinders and the press, couch, and calendar rolls of paper machinery, and in other places where frequent small changes of speed are required, and have come into general use for such purposes.

Messrs. Stow & Burnham, of Philadelphia, exhibited the Stow flexible shaft, with tools and machines for operating in connection therewith. The construction of the shaft will be understood from the illustration, Fig. 35. It is made up of a series of coils of steel wire wound hard upon each other, each alternate layer running in an opposite direction, and the number of wires in different layers varying according to the work the shaft is adapted to. On being brought to size, about one and a half inches at each end of the shaft is brazed solid, and to the solid ends fittings are attached, one to receive the tools to be operated, the other to receive the operating pulley, which in turn receives its power from a round belt. Surrounding the shaft proper is a case consisting of a single coil of iron wire, the internal diameter of which fits loosely on the outside of the shaft, and is covered with

some flexible material,—leather preferably,—over which, at each end, a ferule is fastened, and to the ferule, at the end opposite the frame which carries the pulley, is screwed the hand-piece as shown.

FIG. 35.



Flexible Shaft, Stow & Burnham, Philadelphia, Pa.

Motion is usually transmitted to the pulley on the shaft by a flexible cord running over leading pulleys, some of which have wood screw shanks, which can be screwed into any of the wood-work of the building, while others are provided with hooks, and may be "triced up" to any point. The shaft and attachments enable power to be transmitted readily to all positions and applied in any desired direction. Augers, drills, and metal- and steam-working tools of various kinds, are provided for attachment to the shaft, the speed being reduced by gearing for the heavier operations.

Excellent wooden pulleys were exhibited by Messrs. A. B. Cook & Co., of Erie, Pennsylvania, and there were many ingenious and valuable devices for use in connection with the transmission of power, involving too much detail for full presentation.

BELTING.

The advantages to be derived from the use of belting for the transmission of power, compared with gear-wheels, particularly in respect to original cost, facility of adaptation, immunity from accident, and reduction of jar and noise, are now well understood, at least in the United States, and even here changes of direction for which bevel-gears were, in certain quarters, considered indispensable not many years since, are now accomplished with belting. A notable instance is in flouring-mills, where "half-twist" belts are run from pulleys on a horizontal shaft directly to pulleys on the vertical mill spindles. Moreover, in whatever the direction belting be run, the motion can, at will, be stopped, and applied with facility and without jar. For this purpose belt-shifters, with loose pulleys, are adapted for narrow belts on parallel shafts; for wider belts, adjustable tightening pulleys are employed, and they may also be used with belts running in any direction, by providing in some cases suitable boxes or channels to form guides as the belt is brought into action.

The rules of different writers for proportioning the more important belts in a manufactory give results widely differing. Mr. J. H. Cooper during a number of years (1869 *et seq.*), collected, and contributed to the *Journal of the Franklin Institute*, particulars as to the power transmitted by large numbers of belts of different sizes, from which it appears that there is no uniformity in the practice on the subject.

The strength of different portions of a first-class oak-tanned hide, adapted for making belts, is set forth in tabular form hereafter.

English belting of different widths tested by Mr. Kirkaldy showed an average tensile strength of 842 pounds per inch of width of single belting, and 1126.6 pounds for double belting, corresponding to a relative strength of 1 to 1.34. (Mr. D. K. Clark's *Manual*, p. 680.)

An article in the *Journal of the Franklin Institute* for January, 1868, by the editor, Professor Henry Morton, gives the following results of tests made by Mr. Henry R. Towne of belts 3 inches wide and 2.17 inches thick:

Ultimate Tensile Strength.	Per Inch of Width.	Per Square Inch of Section.
At lacings	210 pounds.	958 pounds.
At splices or laps	382 "	1744 "
Of solid portions	675 "	3086 "

The ends of belts, in which lacing holes were punched, were usually found to be weaker than the lacings, and the strength of new and partially-used belts was practically identical. It was found as the average

result of 180 experiments with 3-inch belts, under tensions varying from 7 to 110 pounds per inch of width, that on cast-iron pulleys and for 180° arc of contact the sliding tension was 6.294 times the slack tension and the co-efficient of friction 0.5833. To provide for contingencies which might arise from various causes, such as moisture in the atmosphere, the interposition of a stratum of air between the belt and pulley at high velocities, etc., Professor Morton adopts only $\frac{6}{10}$ of 6.294, or 3.776, as the maximum practical value, giving a friction co-efficient of 0.423. These values are about one-half greater than those of M. Morin.

Professor Morton calculates the maximum working strain, per inch of width, transmitted by belts having a working strength of $66\frac{2}{3}$ pounds, per inch of width, by means of the following formula, deduced from Rankine's formula: (*Applied Mechanics*.)

$$W = 66\frac{2}{3} (1 - 10^{-0.003206 \alpha})$$

W = the working stress transmitted per inch of width, in pounds.

α = the arc of contact in degrees.

Upon the basis of Mr. Towne's experiments, as discussed by Professor Morton, Mr. D. K. Clark, in his *Manual*, p. 750, presents a table showing the driving-power of leather belting .22 inch thick, per inch of width, for arcs of contact from 90° to 270°, together with the maximum transmitted stresses and other information relating to the subject, which is so complete that it is presented (with slight changes in the headings only) in preference to formulæ the writer had at an earlier date prepared on the subject. The maximum transmitted working stresses calculated by Professor Morton by means of the preceding formula are given in column 2. The sum of the tensions in column 6 was calculated, in each case, by adding to the transmitted stress in column 2 twice the difference between it and $66\frac{2}{3}$. The last column gives the resultant stress by the parallelogram of forces, caused by the tensions of the belt on the bearings of the shaft.

DRIVING-POWER OF LEATHER BELTS.

Maximum working strain, $66\frac{2}{3}$ pounds per inch of width, single thickness.

1	2	3	4	5	6	7
ARC OF CONTACT.	MAXIMUM WORKING STRESS TRANSMITTED PER INCH OF WIDTH.	POWER TRANSMITTED PER INCH OF WIDTH.			SUM OF THE TENSIONS ON BOTH SIDES OF BELT PER INCH OF WIDTH.	RESULTANT PRESSURE ON THE JOURNALS PER INCH OF WIDTH OF BELT.
		At a Velocity of Belt of 1 Foot per Second.	Per Foot of Diameter of Pulley, for each Revolution per Minute.			
Degrees.	Pounds.	Horse-power.	Horse-power.	Foot-lbs.	Pounds.	Pounds.
90	32.33	.059	.00308	102	101.00	71.42
100	34.80	.063	.00331	109	98.53	75.47
110	37.07	.067	.00353	116	96.26	78.85
120	39.18	.071	.00373	123	94.15	81.53
135	42.06	.076	.00400	132	91.27	84.32
150	44.64	.081	.00425	140	88.69	85.67
180	49.01	.089	.00467	154	84.32	84.32
210	52.52	.095	.00500	165	80.81	78.05
240	55.33	.100	.00527	174	78.00	67.59
270	57.58	.105	.00548	181	75.75	53.56

The table being based on a maximum strain of $66\frac{2}{3}$ pounds per inch of width, provides a factor of safety of 3, at the laced ends of belt, as may be seen by examining the results of the experiments previously given. For belts cemented and riveted in place, as is often done, particularly when a tightening pulley is employed, the quantities in the table can be increased one-half, according to the experiments, and leave a factor of safety at the laps of $3\frac{1}{2}$, and for double belting the quantities can be more than doubled with safety, when the ends are cemented and riveted. An examination of Mr. Cooper's precedents shows that the quantities in the table fairly represent the average practice with large single belts, and that the average practice for double belts would be well represented by multiplying the tabular quantities by $1\frac{1}{2}$. Instances are, however, reported of single belts transmitting strains as high as 136 pounds per inch of width, so that the belts were strained on the working side to 164 pounds or upward per inch of width. It will be seen that such exceptional cases are simply examples of working with a reduced factor of safety, as is common with other mechanism. The power which a belt will transmit with a given tension is varied by the relative positions of the pulleys. When one is nearly over the other the pressure on the lower one is reduced by the weight of the belt, and it may be necessary to use a tightening pulley, particularly when the lower pulley is the smaller.

In proportioning the ordinary narrow belts for use in a manufactory, it is usually considered that one horse-power will be transmitted by a belt one inch wide, running at the rate of 1000 feet per minute, and proportional power for other widths and speeds. Another rule is, that a belt with a section of $\frac{2}{10}$ of a square inch will also transmit one horse-power at the speed named. The strain on belting $\frac{2}{10}$ of an inch thick will be the same by either of these rules, and will equal 33 pounds per inch of width, and 165 pounds per square inch of section.

It will be convenient to recollect that any good belt will safely transmit, with ordinary arcs of contact, 50 pounds per inch of width, and that the safe working strain of gear-wheels is considered to be 400 pounds per inch of width.

It has been ascertained by trial that a belt will transmit about 30 per cent. more power, with a given tension, when the grain or smooth side of the leather is in contact with the pulley than when the flesh side is turned inward. The leather is also less liable to crack, as the structure on the flesh side is less dense and the fibres more extensible. The adhesion of belts is greater on polished than on rough pulleys, and is about 50 per cent. greater on a leather-covered pulley than on a polished iron pulley. Large pulleys and drums may be covered with narrow strips of leather, or with a longer strip wound spirally. Pulley-covers are manufactured in strips of the required width, and reduced to uniform thickness by machinery. Belts should be kept soft and pliable by applying tallow occasionally, and neat's-foot or liver oil, with a little rosin when they become hard and dried. A new belt will often work better after a good greasing.

The principal distinguishing features of the manufacture of leather belting, in connection with some historical references, are concisely expressed in the following extract :*

"When belts were first used as a means of transmitting power, leather was selected as the most suitable material. In those days mill-men and others using belts went into the market and purchased ordinary sole leather, from which, without the aid of any of the mechanical appliances now in use in the business, they made their own belts, and very poor belts they were.

"Some forty years ago, Mr. William Kumble, late of the city of New York,—having noticed the growing popularity of belting, notwithstanding the very imperfect method of manufacture then in vogue, or, to speak more correctly, the entire absence of method, and being fully convinced that, if properly made, it would soon supersede the

* From the *Pictorial Album of American Industry*.

then existing means of transmitting power,—determined to make the manufacture of leather belting a specialty, and we believe he was the first to enter upon it as a business. Before this, little or no attention had been paid to the cutting or stretching of belts. A side of leather was simply cut in strips of the required width, reference being had only to securing the greatest number of feet, without considering the texture of the material, or its natural tendency to stretch unevenly.

“Mr. Kumble's idea was to select his leather with special reference to the making of belts (to so treat it as to render it softer and more pliable than ordinary sole leather), and to use only the best parts of the hide. He also paid attention to so stretching the strips that when placed upon the pulleys they would draw evenly.

“But since these early days the methods of manufacture of belting have greatly improved. The prime requisites of a leather belt are strength, flexibility, and elasticity, and to secure these it is essentially necessary that the best quality of hides should be used. Hides suitable for the manufacture of leather belting can only be obtained from thrifty steers that have attained their full growth and have not been worked,—in a word, prime beef cattle. They must be free from blemish, such as brands, cuts, and scores. Thus the preparation of belt leather really commences in the selection of the green hides. The hides are tanned whole.* Only pure oak-tanned leather will make a perfect band, and the most careful attention must be paid to the cleanliness of the vats and the purity of the liquors.

“Careful manufacturers use scarcely one-third of the area of a hide for belting; all that portion from the horns to the shoulders and all the skirts are waste. From the remaining portion strips are cut lengthwise the hide. These are stretched by powerful machinery and retained at the utmost tension they will stand without injuring the fibre. These pieces are jointed and secured so as to present an even surface to the pulley, and the belt runs as though it was one piece.

“The most perfect belt, especially where great power is to be conveyed, is two-ply. The parts are so lapped that the joints on one side are equidistant from the joints on the other side. The result is a band of immense strength, and perfect in its drawing lines.

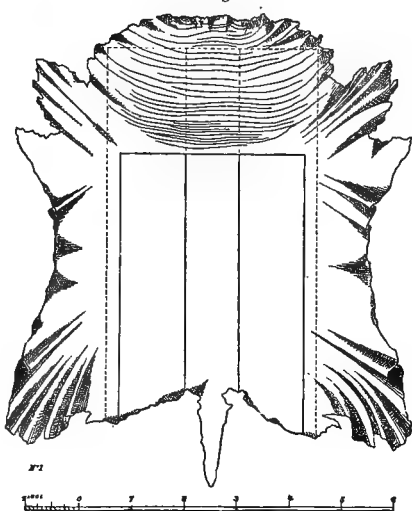
“The length of life of a well-made and properly cared for leather belt has not yet been determined, but we know that there are leather

* This is not true at the present day, as manufacturers with proper facilities tan the centre of the hide used for belting separately, and the rejected portions are tanned by cheaper methods for shoe work.

belts still doing daily duty that have been in constant use for upwards of thirty years, and belts made thirty years ago were not the perfect articles now manufactured."

The value of a leather belt depends greatly upon the discrimination employed in cutting the strips from the tanned hide and in combining them to secure uniformity of stretch so that the belt will run straight. In Fig. 36 is represented a tanned hide of ordinary shape, with the principal folds shown by the shading.* The portion inclosed in black lines is that from which the most enduring and straightest belts are made, being that part of the hide in which the elongation under strain and the ultimate strength are most nearly equal. The results of trials of the strength of this portion of the hide are shown in the following table, and were derived from separate tests of 48 pieces, cut from a side of leather, each $11\frac{3}{4}$ inches long and 2 inches wide, which are shown in relative position in the table, the top pieces being at the centre of the hide, and each piece marked with its ultimate stretch in pounds, elongation in fractions of an inch, and the weight of the piece in ounces and drachms.

FIG. 36.



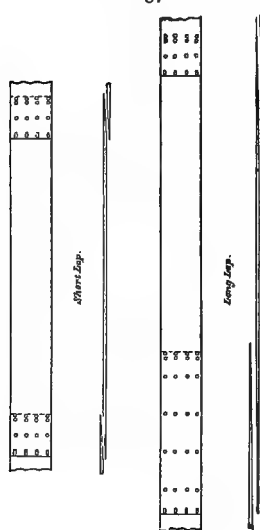
2,000 $\frac{1}{4}$ 3	2,050 3-16 3.1	2,150 3-16 3.2	2,175 $\frac{1}{4}$ 3.3
1,400 9-32 2.12	2,000 $\frac{1}{8}$ 3	2,625 3-16 3.4	2,325 7-32 3.4
2,000 $\frac{1}{4}$ 2.11	2,075 3-16 3.1	2,375 7-32 3.4	2,175 7-32 3.5
2,075 $\frac{1}{4}$ 2.12	2,700 7-32 3.3	2,600 7-32 3.4	2,275 5-32 3.7
2,450 $\frac{1}{4}$ 2.13	2,325 9-32 3.7	2,575 11-32 3.8	2,225 7-32 3.10
2,475 $\frac{1}{4}$ 3	2,975 5-16 3.6	3,200 9-32 3.10	2,175 $\frac{3}{8}$ 3.10
2,575 11-32 3.2	2,875 9-32 3.7	3,475 11-32 3.13	1,850 11-32 3.11
2,675 11-32 3.2	3,075 11-32 3.8	3,450 9-32 4	1,950 $\frac{1}{4}$ 3.11
2,650 $\frac{3}{8}$ 3.2	2,900 9-32 3.6	3,150 3-16 3.15	2,225 $\frac{1}{4}$ 3.10
2,800 $\frac{1}{4}$ 3.1	3,050 5-16 3.6	2,850 $\frac{1}{4}$ 3.13	2,275 3-16 3.7
2,700 $\frac{1}{4}$ 3	3,150 7-32 3.5	3,000 3-16 3.10	2,600 $\frac{1}{4}$ 3.5
2,650 $\frac{1}{4}$ 2.13	3,000 7-32 3.4	3,400 $\frac{1}{8}$ 3.6	2,550 $\frac{1}{4}$ 3.4

The pieces cut for belting from the central section, inclosed in black

* The illustrations, Figs. 36 and 37, also the table following, are from the publications of Messrs. J. B. Hoyt & Co., of New York, manufacturers of leather belting.

lines in Fig. 36, are comparatively short, and are put together with short laps, as shown at the left in Fig. 37, all the pieces running the same way of the leather. When cheaper belts are required, the parts inclosed by the dotted lines are available, in which case the alternate pieces are reversed, and the ends cut from the shoulder joined together in a long lap and the opposite ends by a short one, so that the belt consists of longer pieces than before, with long and short laps alternating. It is evident that pieces may be cut in such locations that their two sides will not stretch alike, and the strength of the belt be reduced to that of the weaker portions of the hide; so also there may be a number of intermediate cuts. In this manner the cost of belting may be varied by as much as 15 to 20 per cent. when using the same stock. It should, however, be observed that pieces which will stretch differently on the two sides may, to a certain extent, be joined

FIG. 37.



so that the greater stretch will take place alternately on opposite sides of the belt, and thereby prevent important deviations from a straight line when the belt is in motion. Large quantities of the cheaper belting are used, especially where ample pulley-surface can be obtained for the power transmitted.

In making double belts, the pieces may be so selected and combined as to produce the best results under severe strains, and instances are recorded where a single belt, which in practice proved to be of insufficient strength, was made to do the work satisfactorily by reinforcing the outer edges, only, with narrow belts.

Belts are made from leather tanned by various processes. A considerable number were shown made from hemlock-tanned leather and some from Union leather, or that tanned with a mixture of hemlock and oak bark, in the proportion of about 10 to 1. Some of these belts had been colored and buffed to imitate oak leather, and it is claimed that all such belts lack endurance compared with those made from well-filled oak-tanned leather.

Specimens of belts made with chemically-tanned leather were exhibited, but did not appear well calculated to resist moisture. It is a question whether leather which is porous to a certain extent may not, in many locations, get well filled with the grease and shop-dust which accumulate on all belts, and thereby the advan-

tages of original flexibility be secured with a satisfactory measure of durability.

The largest belt ever constructed was exhibited by Messrs. J. B. Hoyt & Co., of New York. It was made for Messrs. Jessup & Moore's Augustine (paper) Mill, Wilmington, Delaware, and was 5 feet in width, 186½ feet in length, and weighed 2212 pounds. Messrs. Hoyt & Co. use leather made from selected hides, adapted for belting, tanned with oak bark, in their own tanneries, at Pawpaw, West Virginia; at Everett and Rays Hill, Pennsylvania; at Chattanooga, Tennessee, and at Flintstone and Cumberland, Maryland. They manufacture short lap-belting only, unless long lap is ordered; but, as tanners, sell leather to other belting firms, some of whom have special methods of finish by which their products are distinguished. Other firms have facilities of a similar nature, though some are embarrassed by location in getting a full supply of oak bark.

So many of the manufacturers of leather belting employ to a great extent similar workmanship, and the same methods of manufacture to similar qualities of leather, that it is unfortunate, on account of space, that special features can only be referred to.

There are some 70 to 80 manufacturers of leather belting in the country, and the value of the sales annually is estimated at from \$2,500,000 to \$3,000,000.

The large belts used to drive the main line of shafting were furnished by different exhibitors, and all, without exception, appeared to excellent advantage. A few embodied peculiarities in construction used by the manufacturer for special locations. The list is as follows: Shaft No. 1, G. S. Fales; No. 2, Page Belting Company, Concord, New Hampshire; No. 3, Alexander Bros., Philadelphia, Pennsylvania (one of their patent double belts); No. 4, Charles A. Schieren, New York; No. 5, Josiah Gates & Son, Lowell, Massachusetts (belt secured with pegs, well adapted for damp locations); No. 6, Anton Heim, New York (belt fastened with cement only); No. 7, J. B. Hoyt & Co., New York; No. 8, A. Burgess & Son, Providence, Rhode Island; Annex No. 3, Thomas Rorer, Philadelphia, Pennsylvania (combined leather and canvas).

Messrs. P. Jewell & Son, Hartford, Connecticut, who manufacture large quantities of leather belting, showed, in connection with their exhibit, belt-laces tipped with metal, like shoe-strings, the advantages of which those having practice in a large establishment will not be slow to realize.

Messrs. Chatfield, Underwood, & Co., of New York, exhibited angular belting, consisting of a narrow double belt, to which was se-

cured at close intervals leather blocks of V-shape, adapted to run in the V-groove of a pulley. With this belting additional adhesion is obtained with less initial tension, and unusual changes of direction can be made with great facility.

Rubber belts were exhibited by the Gutta-Percha & Rubber Manufacturing Company, and by the New York Belting & Packing Company. The first company had a belt in use in the saw-mill; the latter furnished the belt driving the west shaft in the Hydraulic Annex, which was used much harder than any other running at the Exhibition, the power taken from the shaft being considerably greater than was at first anticipated.

The Messrs. Crane Bros., of Westfield, Massachusetts, exhibited Japanese paper belting. One of moderate width was running in Machinery Hall, and remained in good condition throughout the Exhibition.

In this connection should also be mentioned a fine exhibit, by the firm of John A. Roebling's Sons, of Trenton, New Jersey, which included cables adapted for rope transmission, and iron, steel, and copper wire and wire rope for all purposes. Many improvements have been made by this firm in the manufacture of wire. The lengths of single pieces have been much increased, and particular pains taken to secure uniformity in the product. A small section of one of the great cables for the East River bridge, designed by the elder Roebling, attracted much attention. It contained 6000 No. 7 galvanized cast-steel wires, with an estimated ultimate strength of 22,300,000 pounds.

There were three exhibits of leather belting from Belgium (including samples of hair belting), one from Norway, two from the Netherlands (including samples of hair belting and raw-hide), and one from Russia. The samples were not extensive, but the leather was well filled, and the belting very well finished.

Mr. B. Godfredson, of Copenhagen, Denmark, exhibited a number of articles made from a composition of leather scraps, rubber, etc. A belt of this material, $2\frac{1}{2}$ inches wide and $\frac{1}{10}$ inches thick, which contained an insertion of canvas, was quite pliable, and showed on trial an ultimate tensile strength of 2250 pounds.

Mr. Bruno Hofwark, of St. Petersburg, Russia, exhibited wire belting which was quite a novelty and well worthy of attention. Wire about $\frac{1}{16}$ inch in diameter was wound in link-shape around two larger cross-wires, forming broad, short links, which were joined together by the cross-wires. The belts were to be used on leather-covered pulleys, and were stronger than leather belting.

The Ewart Manufacturing Company, Chicago, Illinois, exhibited chains for transmitting power, made up of open detachable links, one end of each being formed into a hook, the other being cylindrical, to connect with a hook on a similar link; in which way a sufficient number of links are connected together to make up the length desired (Figs. 38 and 39). The links couple only in the position shown at the left, and the backs of the hooks being run to the pulleys

FIG. 38.

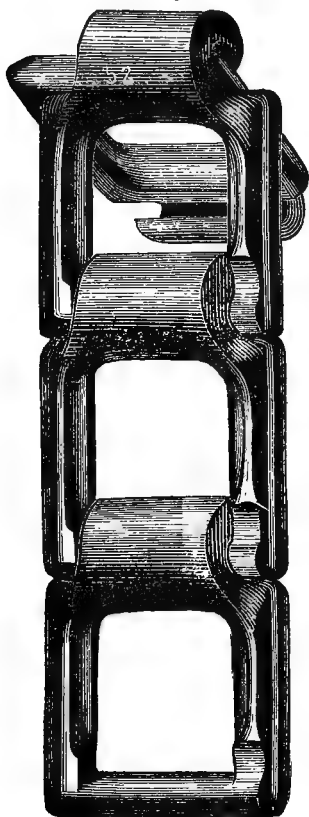
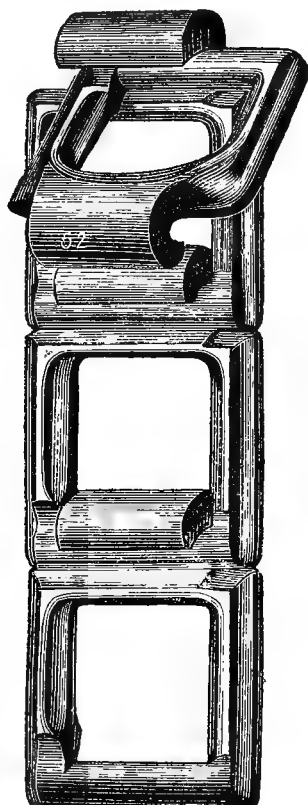


FIG. 39.



Ewart's Chain for Transmitting Power.

they are not liable to become detached. The chain transmits motion positively in connection with wheels toothed to engage with the links, and is readily adaptable for a great variety of uses. Special attachments are formed on links for the connection of arms, buckets, slats, rollers, or the like, to adapt the chain for conveying grain, ores, straw, saw-dust, etc.

Several hoisting- and conveying-machines were exhibited. In that of Nicholas Liarsky Smelensk, Russia, carriages were run on elevated removable rails, provided with suitable supports. All the parts were portable, and the details well designed to secure facility both in erection and operation.

In the plan exhibited by the United States Hoisting & Conveying Company, of New York, a wire rope is stretched over the place where the goods or minerals are to be handled, on which runs a two-wheeled carriage for transporting the load. The operating-rope is carried from the motive-power around a pulley near the end of the supporting wire rope, and, passing through a pulley on one end of the carriage, is attached to the other end, and receives between the two points of support a pulley carrying a hook on its top end and a bucket below. In operation the carriage locks itself fast to a chock secured to the supporting-rope at the loading-point, thereby disengaging the hook on the block carrying the bucket below, so that by slacking the hoisting-rope the bucket is lowered to be filled, and upon raising it to the carriage, it hooks itself fast thereto and releases the carriage from the chock on the rope, when, by slacking the hauling line again, the carriage runs out on the rope by gravity, and at any desired point the load may be dumped by simply checking its velocity. Sometimes, however, another chock is secured to the rope and the carriage provided with hooks and attachments, whereby the load may be lowered at that point and the bucket raised into position again before the carriage is hauled back. All operations are performed by the engineer by stopping, slacking, and reversing the operating-rope at the proper time. This apparatus has produced great saving to railroad contractors, coal-dealers, gas-works, etc., and in different forms its introduction for various purposes is being rapidly extended.

ELEVATORS.

In most of the elevators exhibited the car was supported by wire ropes, which were operated in many cases by special engines attached to the winding-drums. In the engines for this purpose at the Exhibition, the main valves were made with little or no lap, and set without lead, and the engines were reversed by simultaneously reversing the currents in the main steam and exhaust connections in the same way the currents are reversed to the ends of a steam-cylinder. In other cases double ports, controlled by reversing valves, are run from each end of the cylinder. Those on one side lead directly to the nearest ends of the main valve, and are used for raising the load,

and those on the other side cross each other and lead to the farther ends of the main valve, and are used for lowering the load. The ordinary link motion is also frequently employed with simple slide valves.

Messrs. Otis Bros. & Co., New York, use vertical engines, piston main valves, disk reversing valves, and rack-and-pawl safety-attachments. As an additional safety apparatus, the counter-balance rope is wound on a drum at the top of the building, which is held fast by a brake, released by a centrifugal governor, when in case of breakage speed becomes excessive.

Messrs. Stokes & Parrish, Philadelphia, Pennsylvania, and the Crane Bros. Manufacturing Company, Chicago, Illinois, use slide-valves, with covers over them, to receive steam pressure in the chest, and to permit the reversal of currents between the centre and ends of the valve proper. In addition to racks and pawls, duplicate ropes are provided, which are run ordinarily under very light strain.

Messrs. Andrews & Bro., New York, use for their elevators a pair of their oscillating engines, previously described, the shaft of which runs directly through the main drum, and carries on an eccentric the inner spur-wheel shown in Figs. 40 and 41, which does not revolve, but is

FIG. 40.

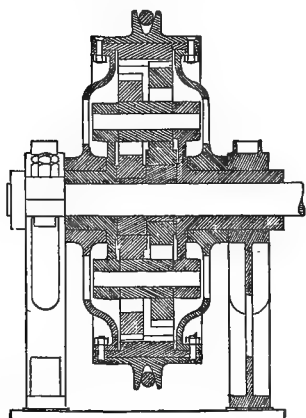
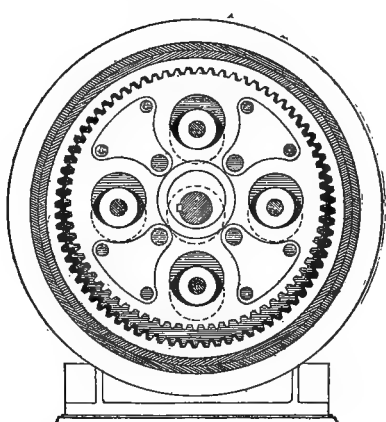


FIG. 41.



Elevator Drum with Differential Gear, Wm. D. Andrews & Bro.

shifted bodily in a circle by the eccentric, rotation being prevented by four stationary guide-rollers in the circular openings shown in the wheel. The teeth of the spur-wheel engage with the internal gear of a wheel attached to the main drum, the result being that for one revolution of the inner wheel the outer wheel is advanced the differ-

ence in the number of teeth, of the two, or four teeth in the case shown. The inner wheel is duplicated, and operated by an eccentric set opposite the other to equalize the strains. As shown in Fig. 40, the guide-rollers are attached to disks with separate hubs or bosses secured to the frame, on which bosses the winding-drum revolves. The apparatus attains reduction of speed in a remarkably compact form, and so many teeth are in contact, and other wearing surfaces so large, that wear should not be excessive. The main ropes of the elevator run in V-grooves in the engine-drum, and adhesion is maintained by the counter-balance wheels. A separate rope is moved simultaneously with the main lifting-ropes, the office of which is, in case of accident to the main ropes, to simply hold up wedges in suitable strong jaws inclosing the guides, the effect being that when the car moves down upon the wedges the latter are at once tightened between the guides and rollers in the jaws, and prevent the car from descending farther. The firm fearlessly cut away the main rope at any point desired, to show the positive action of the safety-apparatus. With the usual racks and pawls the springs sometimes fail to act with sufficient power, when a break takes place in the rope back at the engine, so that there is considerable rope to be "overhauled" before the pawls can be shot into the racks.

In the exhibit of Joseph Goldmark, New York, links are carried up in inclosed guides, which, in case the car falls, double up and catch fast, so as to stop the descent.

Messrs. Tatham Bros., New York, showed a safety-attachment for elevators, in which side-arms and a connecting cross-bar are kept in vibration as the car moves by rollers in sinuous grooves in the guides. If the speed becomes too high in descending, the whole vibrating frame is raised in contact with projections on the bottom of the car-frame, and the descent stopped. This has been proved effective in handling heavy masses of lead in the establishment of the exhibitors. Several devices for grappling the guides were shown, to take the place of the ordinary racks and pawls.

A number of models of hydraulic elevators were exhibited, most of which provided to operate the car by wire ropes connected to the hydraulic rams by multiplying-pulleys, variously arranged.

Mr. W. H. Harrison, Philadelphia, Pennsylvania, showed a small telescopic elevator, in which one tube is forced out of another, successively, to raise the car. This secures the safety of any form of hydraulic elevator, but permits shorter tubes, and requires less depth of base tube. The large elevators in the pavilions of the New York Court-House and Post-Office, New York City, which were super-

intended for the United States Government by the writer, are on this plan, though made by other parties, and are provided with internal dash-pots, to stop the jars when tubes meet. This method is well adapted to secure safety, but involves too much expense to come into general use.

In this connection, it should be mentioned that Messrs. Williamson Bros., Philadelphia, Pennsylvania, exhibited hoisting-engines of superior design and workmanship.

STEAM MACHINERY.

BOILER PROPORTIONS.

A report of the trials of the principal steam-boilers exhibited is hereto appended. From the descriptions and sketches embodied in the report it will be seen that most of the boilers were of the so-called "sectional" type, in which the water is contained in small pipes and chambers, to obtain a high factor of safety, though some of the ordinary types were also represented. There were prominent differences in the several boilers in the governing proportions, and in the number, shape, and arrangement of the parts, and it was expected that a comparative trial would show interesting results due to variations, which are desirable in investigating general laws. The experiments do not indicate that mere peculiarities of arrangement or of mechanical details affect, to any material degree, the comparative efficiency of boilers. On the contrary, it appears that, in designing mechanical details to secure the all-important requisites of safety and durability, the proper governing proportions have been lost sight of, for many of the boilers; and, though the results shown are, on the average, better than those published for ordinary boilers, none are equal to those obtained with boilers of the marine type, which have been gradually improved by repeated experiment.

It is believed that a boiler with any kind of mechanical details and arrangements, not absolutely faulty, can be proportioned to give the same evaporative efficiency as one of any other form; and in view of the great importance of apparatus for the generation of steam to the industries of all nations, and the special value of improvements tending to the economy and safety of such apparatus, it has been considered proper to collate the results of experiments with other boilers for comparison with those obtained with the boilers on exhibition, and to present therewith general conclusions, which will enable the results to be practically utilized through future improvement.

A large number of experiments with steam-boilers are described in scientific journals and publications, prominent among which are the experiments made at various times for the British Admiralty, those for the United States Navy Department, those made at various national and local exhibitions, those made in 1859, 1862, and 1874 by the *Société Industrielle de Mulhouse*, and elaborate experiments on locomotives made by Mr. D. K. Clark. The most valuable of all for the present purpose appear to be those made during the years 1858 to 1866 for the United States Navy Department, under the direction mainly of Chief Engineer B. F. Isherwood, U.S.N., who was most of that time Chief of the Naval Bureau of Steam Engineering.* Boilers of the water- and fire-tube types, constructed for naval steamers, were tried with great care under all possible conditions as to rate of combustion, relative size of grate and of area for draft, etc., and all the results were carefully tabulated for reference.

The experiments made previous to the year 1864 left so many questions to be settled as to the proper type and proportions of boilers for the naval service, that a commission of eminent civil engineers was appointed to conduct further investigations, under whose direction two marine boilers were constructed, one with vertical water-tubes arranged above the furnace, the other with horizontal fire-tubes in similar position, with which 177 experiments of 48 and 80 hours' duration were made, during the years 1865 and 1866, reports of which were printed and transmitted to the Navy Department. The experiments were all made by the same force, with similar fuel (anthracite), and great care was taken to secure uniformity in management, so as to determine accurately the true modification in result, due to the particular change of condition or proportion under trial.

The results of several of the series of experiments are plotted on the accompanying diagrams, 42 and 43, which, as indicated by the marginal notes, show the relation between the weights of combustible burned per square foot of heating surface, and the weights of water evaporated at atmospheric pressure from a temperature of 212° F. by each pound of combustible.

The relative quantity of heat transferred through the heating surfaces to the water in a boiler, from incandescent fuel or the heated products of combustion, is a maximum in the furnace, in which the difference in temperature between the heated gases and water is

* See Isherwood's *Engineering Precedents*, vol. ii., and *Experimental Researches in Steam Engineering*, vols. i. and ii.

greatest, and rapidly decreases as the difference in temperature is diminished by the exposure of the heated gases to successive areas of water-heating surface. An expression for the rate of conduction has been developed by M. Peclet, and Prof. Rankine shows in his treatise on the Steam-Engine that this rate is very nearly proportional to the square of the difference in temperature. The higher values determined in this way, which are due to radiation and conduction from the fuel in the furnace, may be integrated with the successive reduced values, due to the decrease of the difference in temperature, as the gases move toward the chimney,—when, as may be represented graphically, the total areas included between the curve and axes will represent the efficiency for the total heating surface. In the diagrams herewith presented it has been found convenient to represent the efficiency of different total amounts of heating surface by the ordinates of a curve, deduced by comparison with the results of experiments.

The experiments best suited for this purpose were found to be those made with the vertical tubular boiler. This boiler was tested at different rates of combustion with a constant proportion of heating to grate-surface, the results of which are shown by the connected points designated R on diagrams 42 and 43. The low results at the higher rates of combustion in this case are due to the fact that it was necessary to force the draft with either a jet or a blower. Other experiments were made, reducing the grate, using the maximum combustion possible with such reduced grate as shown in the plotted experiments designated U, and experiments were also made with reduced grates with a rate of combustion less than the maximum, as shown in experiments designated T. The most valuable series of all were, however, those in which the evaporative efficiencies for different proportions of heating surface were tested, first, by stopping entirely the draft area through tubes, and taking off the products of combustion to the chimney through openings in the back connection, the results of which are plotted at the right on diagram 43; and, second, by successively removing transverse rows of tubes from the vertical tubular boiler, keeping the grate constant. The results of this, for maximum combustion are designated Q, on diagram 42, and for reduced combustion by S, on the same diagram. It will be seen that the results of the several experiments, except those with forced combustion, are very well shown by the upper curve marked O, on diagrams 42 and 43.

It is evident that as the rate of combustion per unit of heating surface decreases, or what is the same thing, as the heating surface

DIAGRAM 42.

Curves showing the economical efficiency of steam-boilers at different rates of combustion per unit of heating surface.

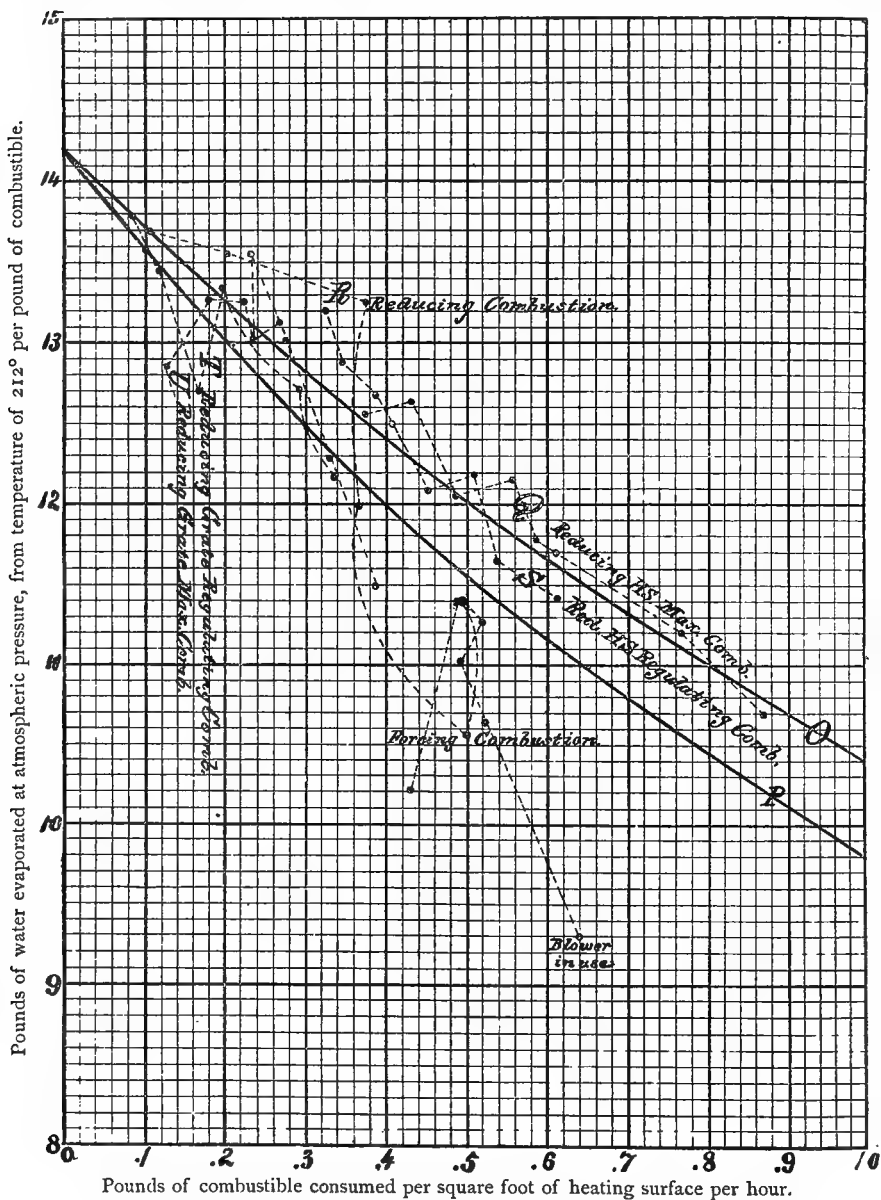


DIAGRAM 43.

Curves showing the economical efficiency of steam-boilers at different rates of combustion per unit of heating surface.

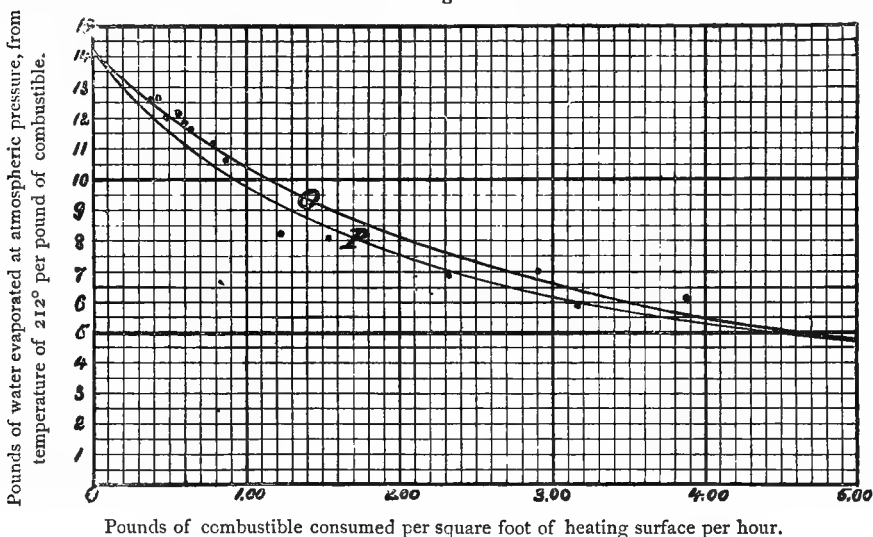
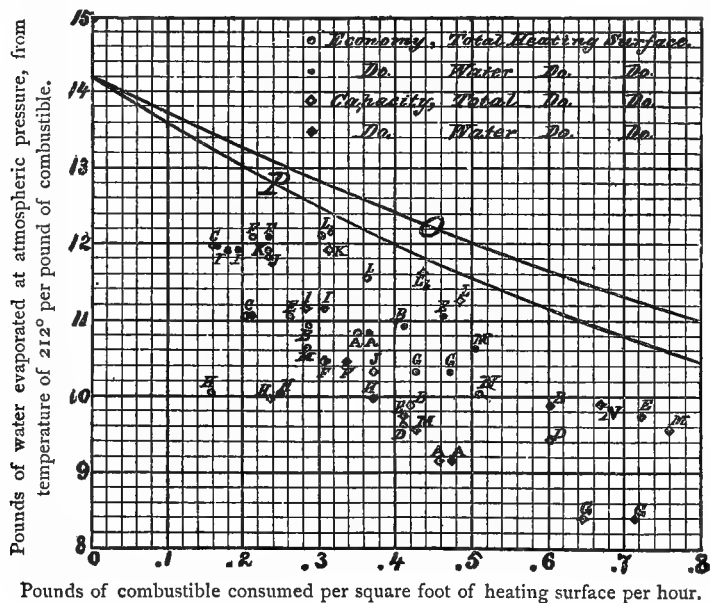


DIAGRAM 44.

Showing the performances of the steam-boilers tested at the Philadelphia International Exhibition



per unit of combustible consumed is increased, the amount of heat absorbed will be increased until the highest evaporation theoretically possible is obtained.

Let c = number of pounds of combustible consumed per square foot of heating surface per hour, and E = the number of pounds of water evaporated on what we will term the standard basis, viz., at atmospheric pressure from temperature of 212° per pound of combustible. Then the heating surface per pound of combustible consumed $= \frac{1}{c}$, which equals infinity when $c = 0$, and the total calorific value of one pound of combustible should, under absolutely theoretical conditions, be utilized when the heating surface to receive it is indefinitely large, or when $c = 0$.

The calorific value of anthracite combustible is usually considered to be equal to that of the carbon element, or 14,500 heat-units, equivalent to the evaporation of 15 pounds of water on the standard basis above explained, but to obtain such a result would require absolutely perfect combustion in oxygen. Under practical conditions combustion must take place in air and an excess be supplied for dilution; and supposing this to be true also at the limit, and that the air for dilution equals that required for combustion, as is not infrequently the case, the evaporation per pound of combustible would be reduced by the amount of heat required to raise the temperature of about 24 pounds of air from, say 72° to the temperature of evaporation, or 212° , a range of 140° , and the specific heat of air being .238, the calorific value of one pound of combustible is, for practical comparison, $14,500 - (24 \times 140 \times .238) = 13,700$ heat-units, equivalent to an evaporation of 14.2 pounds of water, which may be called the theoretical evaporation practicable at atmospheric pressure from a temperature of 212° (the standard basis).

In this way the length of the first ordinate of a curve is established in a satisfactory manner, and it is gratifying to find that a curve, from the point thus determined, accurately corresponds with the results of the experiments. A number of experiments plot above rather than below the curve, but such results may be due to the use of coal containing a little more hydrogen than average specimens. The commencement of the curve could be located higher by considering a less excess of air, or including more hydrogen, but as the experiments were made without testing the quality of the steam (though pains were taken to give large outlets so as to prevent entrainment), it is thought that the curve as shown represents the best results possible under average conditions. The curve adopted is a hyperbola, the

axes of which are parallel to, but do not coincide with, the lines from which the diagrams are graduated. Representing the rate of combustion per square foot of heating surface by c , and the evaporation on the standard basis by E , as before, the several values of E from which the curve O was plotted may be found from the equation :

$$E = \frac{46.045}{c + 3.016} - 1.067. \quad (1)$$

The experiments made by the Commission with the horizontal tubular boilers do not correspond as well with each other as those from the vertical tubular boiler. Plotted in connection with a large number from other boilers, the average results are lower than those shown by the curve O , though some are higher. It seems probable that the difference is due to the customary differences in proportion, which will be referred to hereafter, rather than to the type of boiler. As ordinarily proportioned, however, the best results possible under average conditions are better shown by the curve P , which intersects the curve O at points $c = 0$ and $c = 5$, the latter representing a reduction of heating surface to double that of the grate when 10 pounds of combustible are burned per square foot of grate per hour. The ordinates of the curve P between the limits above mentioned may be

$$\text{found from the following equation : } E_P = \frac{27.287}{c + 2.04} + .824. \quad (2)$$

On diagram 44 the results of the trials of the boilers at the Exhibition are presented in connection with the curves of maximum performance O and P previously developed. Each experiment for capacity is represented by a diamond, which is in outline to represent the combustion per square foot of total heating surface, and black for the combustion per square foot of water heating surface. For the economy trials, outlines and black circles refer similarly to the combustion per square foot of total and of water heating surface, respectively. The letters refer to the several boilers tested, and are given in connection with the designation of the boilers in the tables of the boiler report hereto annexed. It will be understood that the curve O represents the maximum evaporation practicable with anthracite coal of average quality for different rates of combustion per square foot of heating surface. For instance, when two-tenths of a pound of combustible is consumed per square foot of heating surface per hour, the evaporation on the standard basis (*viz.*, at atmospheric pressure from a temperature of 212° per pound of combustible) should be 13.25 pounds, and with a combustion of eight-tenths of a pound of combustible per square foot of heating surface, or four times as much as before, the evaporation on the standard basis should be 11 pounds, or

.83 of the previous result. The water evaporated per square foot of heating surface per hour in the two cases respectively would be 2.65 and 8.8 pounds, or as 1 to 3.32. Hence it appears that, within the limits mentioned, to effect a saving of one-sixth of the fuel the heating surface must be increased $3\frac{1}{3}$ times, or, conversely, that, within the same limits, a given power may be obtained with a boiler containing less than one-third the heating surface of another by the use of one-fifth more fuel, and it may be stated in general that a large increase in power may be obtained with a comparatively moderate reduction of economy. The curve O shows with satisfactory accuracy what the relation should be, and furnishes ready means for explaining results with boilers which have been considered remarkable, and even wonderful.

The conditions of each particular case must determine the question whether a saving of fuel, with increased first cost, is of greater importance than an original saving in cost of construction. For permanent works first cost can be increased till the saving equals the interest; for portable boilers reduction of weight is important; and, for any case, reasons will appear to determine the proper relation of the original and ultimate cost on the basis furnished by the curve O and equation 1, and manufacturers may be enabled to guarantee any possible result.

The development of a satisfactory relation between the power and economy of a boiler permits a modified expression for the efficiency. The efficiency, as ordinarily stated, may be termed the ultimate efficiency, and equals the actual evaporation reduced to standard basis divided by the evaporation due to the calorific value of the fuel, or 15 in this case. The maximum practical evaporation in any given boiler, with good proportions, depends upon the rate of combustion per unit of heating surface, so the performance of the same or different boilers burning different quantities of combustible per unit of heating surface should not be compared by the actual evaporations, but by determining what we will call the "practical efficiency," depending upon the conditions, and equal to the observed evaporation, reduced to standard basis, divided by the value of the ordinate of curve O, due to the rate of combustion, or by the value of E in equation 1.

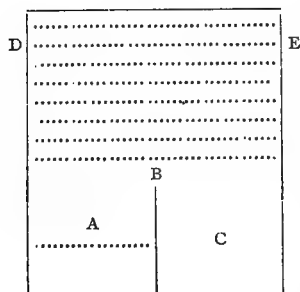
If F = the practical efficiency, e the observed evaporation, reduced to standard basis, and E , as before, the maximum evaporation by equation 1, for a given value of c , then $F = \frac{e}{E}$. For instance, when $c = .4$, $E = 12.41$, hence, if $e = 10$, $F = .81$ only. The mechanical details of a boiler may affect to an important degree its safety and

durability, but not to any great extent its practical efficiency. The results which plot nearest to curve O, in diagram 44, are evidently not due to peculiarities in the construction of the boilers, but simply to the rates of combustion in connection with proper proportions; for the curve has been developed from a theoretical starting-point, and made to correspond with the results of practical experiments with boilers not having the same peculiarities of construction. Most of the experiments, it will be seen, plot much below the curve O, and it is important to ascertain the cause.

Prof. Rankine (*Steam-Engine*, page 281) states that "the free circulation of the fluids which touch the sides of a solid plate is a necessary condition of the correctness of the formula for the conduction of heat through that plate, which has been given in Article 219; and in each of these formulas it is implied that the circulation of each of the fluids by currents and eddies is such as to prevent any considerable difference in temperature between the fluid particles in contact with one side of the solid plate and those at considerable distances from it." The importance of the free circulation of both fluids to secure maximum efficiency is evident, but the attention of writers and manufacturers has chiefly been directed to the circulation of the water, and the loss of efficiency due to the imperfect circulation of the heated gases along the heating surfaces has not been carefully examined. Imperfect circulation of water may cause overheating and danger, but, if the gases do not circulate thoroughly over heating surfaces, a greater proportion of the heat passes to the chimney, with loss, it is true, but without interfering with the regular duty of the boiler. From variations of density, particularly when steam bubbles are formed, a more or less perfect circulation of water will be caused in all locations not exceptionally bad, but as the heated gases are in rapid motion toward the chimney, there is little opportunity for the transfer of particles from the interior to the exterior of the various streams, and the heat of the interior portion can be only imperfectly transferred to the heating surfaces by radiation. Moreover, in many boilers there are lines of least resistance, which the heated gases may take on the way to the chimney, that do not lie directly along the heating surfaces, and in other cases there is sufficient area to pass the gases along or between a portion of the heating surfaces in the most direct line to the chimney, so that sluggish currents only are maintained in other portions. The result is that some portions of the heating surfaces have a very low evaporative efficiency, which causes a low average result. For instance, if Fig. 45 represent one of the type of boilers in which a grate, A, is one side of a bridge-wall, B,

and a flue, C, connecting to chimney on the other side, and the dots represent heating surface upon vessels of any shape, it is evident that if the space over the bridge-wall, B, be sufficient to pass the volume

FIG. 45.



of the gases, a very small proportion will circulate in the chamber above; and, even if the bridge-wall be continued upward by a partition between the heating surfaces, evidently the shorter route to the chimney will still be close along and over the top of the partition; and, at moderate rates of combustion, the circulation of gases near the ends, D and E, will be sluggish, and the heating surface there comparatively ineffective. The remedy suggests itself of decreasing the area between

the heating surfaces so as to force a larger portion of the gases to take a more indirect route, and thereby raise the efficiency of heating surfaces more remote from the direct line to the chimney. Mr. Isherwood has discovered that by reducing the cross-area for draft (or the calorimeter as he terms it) of a tubular boiler, the economy is increased; and he accounts for it, partly by the reduced combustion, and partly by the higher temperature in the furnace, due to "the less air dilution attending the less calorimeters."* The latter suggestion does not appear to be supported by later experiments. The general principle appears to be that by judiciously decreasing the area for draft so as to increase the resistance along the most direct lines to the chimney, the products of combustion are better distributed and circulated among and along the heating surfaces, and the average efficiency of the latter increased. It is true that the reduction is unnecessary when there is no well-defined short line to the chimney, as explained hereafter. So, also, some of Mr. Isherwood's experiments appear to contradict the principle. Referring to the experiments with a horizontal tubular boiler on the United States steamer *Miami*, those made at the highest rates of combustion plot very near the curve O. In other experiments made with ferules in the ends of the tubes, reducing the draft area, the results were no higher than before, although the combustion per unit of heating surface was decreased. The explanation is probably as follows: the ferules increased the resistance so that the quantity of gases passing through the several tubes was nearly equalized, but the gases probably flowed along the top of each tube from the con-

* Isherwood's *Experimental Researches in Steam Engineering*, vol. ii. page xcv.

traction at one end to that at the other end, and the bottom of the tube was not as effective a heating surface as if the reduced area had been continued the whole length, for which other experiments show economical results.

From the various experiments, the proper area for draft to pass the gases for a given amount of coal may be readily determined, and appears to be about one-eighth of the grate when burning about 12 pounds of anthracite coal per square foot of grate. This corresponds to a combustion of say 100 pounds of coal per hour per square foot of cross-area of tubes for draft. Facts are not available to show definitely whether it is better to use a constant or graduated area of flues or draft-passages from the furnace to the chimney. As the gases move from one to the other they lower in temperature and volume, hence it would seem necessary to have the greater area toward the furnace, and in practice there is generally a combustion-chamber provided. If, upon leaving the combustion-chamber, the gases be passed through a contracted area to secure distribution, a freer draft should be obtained by slightly enlarging the flues in the direction of the chimney, but such enlarged flues might not be fully filled by the heated gases. In a majority of cases, the flues are of constant area after the combustion-chamber is passed, and the reduction in the volume of the gases by cooling causes such reduction in resistance that a satisfactory draft is obtained; so, on the whole, this practice may be considered the best.

It is recommended that the grate be made of such size that twelve pounds of coal will be burned per square foot per hour under average working conditions, and the rate of combustion should be increased, when the draft will allow, rather than diminished, on account of the carelessness of firemen in attending to large thin fires.

It is believed that the results obtained with the boilers exhibited may be explained in every instance upon the foregoing principles, but it is considered improper to make the application in this place, notwithstanding the fact that nearly every manufacturer may guarantee any performance desired, by ascertaining proper proportions and practically proving their application to his particular details. A few references only will be made, and those of a general character.

First, it will be observed that in a long flue partially obstructed, as in boiler L (Boiler Report, § 47), the resistance in different parts of the cross-section is so nearly uniform that the area may be larger than has been previously indicated. The transverse tubes continually break up the current, and the intermediate spaces allow free opportunity for equalization of pressure. The same fact is true to some

extent when the water-tubes are staggered so as to require the heated gases to take a tortuous course. So also a flue along the bottom of a boiler may apparently be larger than has been stated, as the heated gases will naturally rise against and roll along the heating surfaces unless the direction of the draft tends to carry them away. For a flue above a boiler the reverse is equally true. In other boilers it will be found that the lines of least resistance do not lead directly through the mass of the heating surfaces, and in others so much area is given that large portions of the surface are ineffective.

It should be mentioned, however, that the boilers at the Exhibition gave, on the average, higher results than those published of many trials abroad,—particularly better than those experimented with by the *Société Industrielle de Mulhouse* previously referred to; but the results with the naval boilers previously analyzed are still higher; so there is room for improvement, the direction of which it is hoped will be suggested by the considerations herein expressed.

In proportioning boilers to secure economy the great loss of power necessary should not be overlooked. If insufficient capacity be furnished in any case, dissatisfaction and loss will result, instead of gain. The highest economies cannot be obtained without very high chimneys or the use of mechanical draft. It should be borne in mind also that few boilers, if worked at a less rate of combustion than that for which they were designed, will give as high a practical efficiency as is shown by the curve O of maximum performance. The reduction is less when the passages are broken, as has been explained previously, but so varies with each type of boiler that the law for maximum performance only has been attempted, except in respect to marine boilers with horizontal tubes, represented by curve P, which is of limited application.

The relations between the coal consumed per square foot of heating surface and the evaporation on the standard basis and per square foot of heating surface, are shown in the following table, in connection with the corresponding "ultimate efficiencies" previously explained, and the amounts of fuel and quantities of heating surface required per horsepower on the basis stated in the headings. The experiments appear to show that the water-heating surface only should be included in making the comparison. The explanation of this probably is that steam has lower specific heat than water, and that there is generally little provision for rapid circulation in the steam-space of boilers. When the steam-heating surface is specially effective,—for instance, when considerable superheating is obtained or when the boiler lifts water which is evaporated by the steam-heating surfaces,—a portion of

the latter should be included in applying the formula or referring to the table.

The table is based upon the highest possible evaporation for the several rates of combustion, so for boilers which have not had their proportions adapted to the peculiarities of their construction a large margin should be allowed to secure certainty in the results, for which the performance of the boilers exhibited will be a safe guide.

1	2	3	4	5	6
<i>c</i>	<i>E</i>	<i>cE</i>	$E \div 15$	$34.52 \times 1.2 \div E$	$34.52 \div cE$
COMBUSTIBLE CONSUMED PER SQUARE FOOT OF HEATING SURFACE.	WATER EVAPORATED AT ATMOSPHERIC PRESSURE FROM TEMPERATURE OF 212°.		ULTIMATE EFFICIENCY.	COAL (WITH $\frac{1}{16}$ REF-USE) PER HORSE-POWER PER HOUR.	HEATING SURFACE PER HORSE-POWER.
	PER POUND OF COMBUSTIBLE.	PER SQUARE FOOT OF HEATING SURFACE.		On Basis that one Horse-Power requires 30 Pounds of Water per Hour evaporated at 70 Pounds Pressure from Temperature of 100°, or 34.52 Pounds at Atmospheric Pressure from Temperature of 212°.	
Pounds. Minimum.	Pounds.	Pounds.		Pounds.	Square Feet.
	14.20	.....	.95	.....	.....
.1	13.71	1.37	.91	3.02	25.18
.2	13.25	2.65	.88	3.13	13.03
.3	12.82	3.85	.85	3.23	8.98
.4	12.41	4.96	.83	3.34	6.95
.5	12.03	6.02	.80	3.44	5.74
.6	11.68	7.01	.78	3.55	4.92
.7	11.32	7.92	.75	3.66	4.36
.8	11.00	8.80	.73	3.77	3.92
.9	10.69	9.62	.71	3.87	3.59
1.0	10.39	10.39	.69	3.99	3.32
1.5	9.13	13.70	.61	4.54	2.52
2.0	8.11	16.22	.54	5.11	2.13
2.5	7.28	18.20	.49	5.69	1.90
3.0	6.57	19.71	.44	6.30	1.75
3.5	6.00	21.00	.40	6.90	1.64
4.0	5.50	22.00	.37	7.53	1.57
4.5	5.06	22.77	.34	8.19	1.52
5.0	4.68	23.40	.31	8.85	1.48

CALORIMETRIC TESTS.

The experiments at the Exhibition suggest some improvements in the apparatus for testing the quality of the steam. As stated in the boiler report, the method of condensing all the steam employed by Prof. Thurston is impracticable in most cases. The question is really to select from the various modifications of the original Hirn method of testing a portion of the steam only, and in doing this judgment is required to obtain proper average results. The entrained water may

not be equally distributed in all parts of the cross-section of the current, and portions may be carried along the surface of the pipe. It is considered better, therefore, to take steam to the calorimeter from several points in the main pipe at different distances from the centre, or to withdraw the steam at such velocity that it will take out its proper share of any water present in the form of drops. The pressure in the boiler should, moreover, not be allowed to change during the operation; and to accomplish this, supplies to other sources should be properly regulated. It will be remembered that in M. Hirn's first experiments the amount of heat shown by the calorimeter was in excess, and a paper was written by another to account for this by the transmutation of work into heat. M. Hirn afterwards dissented from this view. Means are furnished by the present experiments to explain the phenomenon. It was provided by the Committee at the Exhibition experiments to withdraw the steam through a perforated cross-pipe in the main steam-pipe. To prevent any material difference of pressure in the two, whereby the steam in the former would receive heat from that in the latter, the perforations were made of larger area than the cross-pipe, and the connection from the latter to the calorimeter-pipe was reduced by a nipple to one-fourth the area of the perforated portion. Notwithstanding this precaution, slight superheating was shown by boilers having no superheating surface, which is held to show that some heat was transferred through the perforated pipe. The amount is, however, proportionally so small that it has not been considered. This influence must have been substantially the same for all the boilers, and the results with two of the boilers compare well with those obtained on the trial of similar boilers in New York, in which trials all of the steam was condensed, if the difference in the rate of combustion and allowances then made be considered.

FIG. 46.

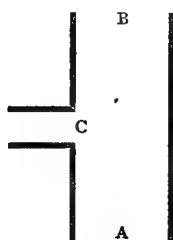
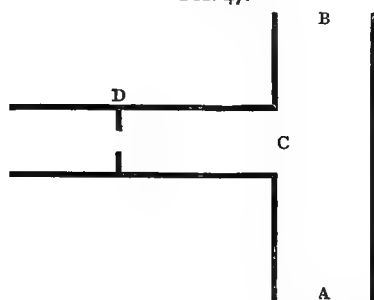


FIG. 47.



In any case, if the main body of the steam be passing through a pipe, from A to B, Fig. 46, for instance, and steam be withdrawn at

a high velocity through a side opening C, the pressure in the latter will be lessened and receive heat by conduction from the surrounding metal, which heat will be supplied, to some extent at least, from the main body of the steam passing toward B.

To prevent this it is suggested to make the opening C quite large, as shown in Fig. 47, and to contract it at a point D, at a considerable distance from the main pipe A B, when the heat yielded up by the metal surrounding the contraction will be derived from the steam about to enter, and no additional heat be received from steam passing to other points. By observing this precaution and taking care also to regulate the flow in the main pipe so that the pressure is not changed when using the calorimeter, it is believed that absolutely correct results will be obtained with apparatus as simple as that used at the Exhibition.

BOILER FURNACES, FIXTURES AND ATTACHMENTS.

An ordinary stationary boiler, used to furnish steam for the engine in the Shoe and Leather Building, was provided with a furnace invented by Mr. J. B. Hoyt, of New York. The furnace proper was an oven lined with fire-brick, and located at one side of the boiler, so that the temperature of the incandescent fuel was not lowered by radiation, and all the heat imparted to the boiler was absorbed from the heated gases. The air introduced to the furnace was heated by passing it through chambers formed in the walls inclosing the boiler. The furnace effectually prevented the formation of black smoke, and experiments made for the inventor by Mr. Theron Skeel showed that there was a perceptible gain from the use of the furnace when burning highly bituminous coal, and that the results were practically the same as with the ordinary furnace when using anthracite coal. These facts appear to indicate that the apparent greater efficiency of heating surfaces exposed to radiation from the fuel, mentioned by M. Peclet, may be due entirely to the higher temperature, and that equal efficiency should be obtained from surfaces exposed to conduction and radiation from the products of combustion at an equally high temperature. It establishes, moreover, the substantial correctness of integrating the efficiencies of the entire heating surface both in and beyond the furnace, as has been done in the previous examination of the subject of boiler proportions.

The well-known Green Fuel Economizer, manufactured by Messrs. Edward Green & Son, of Manchester, England, was exhibited in connection with the Galloway boiler.

The boiler fixtures and attachments referred to the Group included large numbers of feed-water heaters, low-water detectors, water-gauges, automatic boiler-feeders, whistles, steam-traps, grate-bars, tube-cleaners, damper regulators, as well as scale-preventives, boiler covering compounds, etc., to which it is impossible to refer in detail.

BOILER INSPECTION.

The Hartford Steam-Boiler Inspection & Insurance Company exhibited specimens of incrustations, scale, and defective iron from steam-boilers, fragments of exploded boilers, etc., illustrating the hidden dangers incident to the use of boilers not properly attended to, or constructed with poor workmanship or of poor material, all showing that the benefits to be derived from a systematic inspection by experts cannot be over-estimated.

The Hartford Steam-Boiler Inspection & Insurance Company was chartered by the Legislature of Connecticut in the spring of 1866, and commenced active operations at once. The statistics of the company since that time show that there have been some 900 boiler-explosions in the country, by which not less than 1800 persons have been killed and 2000 wounded. Previous to the organization of this company there was no well-established system of boiler inspection in the country. Several States had enacted laws requiring all steam-users to have their boilers inspected at least once a year, but the execution of these laws was lax. The hydrostatic pump was the principal apparatus used, and very little intelligence was brought to bear upon the subject. The system adopted by this company at the beginning was a thorough internal and external examination, with hammer and chisel, when the boiler was cold, at least once a year, followed by visits. The hydrostatic pump was employed only as an auxiliary,—its use, as generally applied, being considered injurious. The company's business extends over a large portion of the country, being confined mainly to stationary boilers. The company employs twenty-seven trained inspectors, who are constantly occupied in examining boilers under its care, and explosions seldom occur where boilers are placed under this rigid supervision. All the boilers inspected and approved are insured against loss or damage arising from explosion. The company imposes no arbitrary conditions, is interested in no patented appliances, but on receipt of the proposal for insurance, together with the inspector's report, the boilers are classified and accepted at a proper rate per cent., unless they are found to be absolutely unsafe, in which case the applicant is furnished with a written

statement of their condition. The policy of insurance covers damage to boilers, building, stock, and machinery, and is a guaranty that the work of inspection has been thoroughly done. The company has some 10,000 boilers under its care. The annual reports of the president of the company contain illustrated descriptions of defects in boilers and of exploded boilers, and will be found both instructive and interesting.

With a view of laying before the group some reliable information of the working of one of the best-known associations for the inspection of boilers abroad, Mr. Charles T. Porter, a member of Group XX., addressed a series of questions to Mr. L. E. Fletcher, chief engineer of the Manchester (England) Steam-Users' Association, which was answered in the following communication, which will be found of great interest.

The Manchester Steam-Users' Association for the Prevention of Steam-Boiler Explosions, and for the Attainment of Economy in the Application of Steam.

OFFICES, 9 MOUNT STREET, MANCHESTER, July 4, 1876.

To the Judges of Group XX., Centennial Commission, Philadelphia.

GENTLEMEN,—In reply to a letter received from Mr. Chas. T. Porter, requesting information as to the working of the Manchester Steam-Users' Association, for the use of the Judges of the International Exhibition, Philadelphia, I beg to forward the following particulars, and in doing so will take up the points seriatim in the order in which they occur in Mr. Porter's letter :

No. 1. "*Term of Existence.*"—The Association was established in the year 1854, and has been in active work ever since, increasing in the number of boilers and the area of its operations.

No. 2. "*Average and Present Number of Boilers in Charge.*"—The number of boilers now under inspection is, as nearly as may be, 3000. The average for the last five years has been 2500.

No. 3. "*Character of the Boilers, and if of Different Types, the Number of Each.*"—By far the greater number of boilers enrolled with the Association are horizontal and internally fired. Speaking approximately, the relative number of the various types is as follows :

50 per cent. are what are termed "Lancashire" boilers,—that is to say, having two internal tubes running through them from end to end in which the fires are placed.

15 per cent. are of the "Cornish" type,—that is to say, having one furnace tube running through it from end to end, in which the fire is placed.

15 per cent. are externally fired, such as plain, cylindrical, egg-ended, colliery boilers ; French or "Elephant" and "Butterly" boilers.

8 per cent. are variations of the "Lancashire" and Cornish boiler, with a number of small flue tubes, some termed "Multiflued" and others "Multitubular," etc.

6 per cent. are of the "Galloway" type.

6 per cent. are of the miscellaneous types, such as boilers at iron-works, heated by flames passing off from puddling- and iron-furnaces, water-pipe boilers, locomotive and marine boilers, and vertically internally hand-fired boilers, etc.

These proportions vary somewhat year by year as boilers are changed.

No. 4. "*Pressure carried between what Limits.*"—All the "Lancashire" boilers made for the members under the inspection of the Association, the ruling diameter of which is 7

feet in the shell, and 2 feet 9 inches in the furnace tubes, are fit for a working pressure, as a minimum, of 75 pounds on the square inch. Many are fit for a working pressure of 85 pounds, others 90 pounds and 100 pounds. No new boilers are made to the Association's standard for a lower pressure than 75 pounds on the square inch. Many smaller boilers are carrying 120 pounds.

No. 5. "*Character of the Examinations made and their Frequency.*"—A complete examination of each boiler is made both inside and outside, when at rest and properly prepared, at least once a year, and more often if necessary,—that is to say, if the boiler does not appear thoroughly sound or repairs have to be examined. Hydraulic tests are also had recourse to when necessary. In addition to the annual thorough examination, two external examinations of each boiler are made per annum with the boilers at work and steam up. This number is a minimum.

No. 6. "*Nature of the Defects discovered and the Number of each per Annum.*"—The following is a list of the defects discovered, with the number of each, for the year 1875:

Furnaces out of shape	.	.	.	.	.	22 defects.	3 dangerous.
Fractures	.	.	.	.	.	87	" 10 "
Blistered plates	.	.	.	.	.	79	" 6 "
Internal corrosion	.	.	.	.	.	163	" 5 "
External corrosion	.	.	.	.	.	104	" 21 "
Internal grooving	.	.	.	.	.	117	" 1 "
External grooving	.	.	.	.	.	9	" 2 "
Feed-apparatus out of order	.	.	.	.	.	1	" ... "
Water-gauges	"	.	.	.	.	7	" ... "
Blow-out apparatus	"	.	.	.	.	14	" 3 "
Fusible plugs	"	.	.	.	.	6	" ... "
Safety-valves	"	.	.	.	.	30	" 18 "
Pressure-gauges	"	.	.	.	.	110	" 7 "
Boilers without glass water-gauges	.	.	.	.	.	2	" ... "
" safety-valves	.	.	.	.	.	8	" 1 "
" pressure gauge	.	.	.	.	.	6	" 4 "
" blow-out apparatus	.	.	.	.	.	6	" ... "
" feed-back pressure-valves	.	.	.	.	.	51	" ... "
Cases of over-pressure	.	.	.	.	.	9	" 5 "
Cases of deficiency of water	.	.	.	.	.	2	" 1 "
Total	.	.	.	.	.	833 defects.	87 dangerous.

No. 7. "*Instructions given to Owners and Firemen.*"—We have no written code, but are thinking of preparing a list of instructions to firemen. All we ask from the owners is to get a good boiler and a careful man. We impose no arbitrary conditions. Information to the owners is always accessible at these offices.

No. 8. "*The Guarantee afforded to Members.*"—The Association guarantees the members freedom from explosion year after year. As a pledge of good faith, the reports are indorsed with a pecuniary guarantee of £300; but the Association has no explosions. The only exception to this was the rending of a furnace through over-heating, in consequence of misuse by the owner, who charged the boiler heavily with caustic soda and arsenic,—bringing down the incrustation, but yet neglecting to blow out. No one was hurt, and the boiler was soon repaired and set to work again. We warn our members against using compositions and neglecting to blow out. We guarantee perfect immunity from explosion provided only they meet us with ordinary fairness. Year after year we are able to report, "*No explosion from any boiler guaranteed by the Association.*"

No. 9. "*The Cost to Members of the Inspection and Guarantee.*"—The charge for inspection is one guinea and a half per annum each boiler, within a radius of 40 miles of Man-

chester; beyond that distance, according to arrangement. There is no charge for guarantee. The Association's guarantee is neither to be bought nor sold. If the Association considers a boiler unsafe, nothing will induce it to say it is safe. If the boiler is safe, there is no need to charge for saying so. The expense is incurred in inspection, and the Association has no explosions to make compensation for.

No. 10. "*The Result of the Work of the Association in Immunity from Accidents.*"—It is presumed that by the word "accidents" is meant "explosions." We do not approve of the word "accidents" as applied to explosions. Explosions in the great majority of cases are not accidental: they arise from known causes. Inspection is able to prevent their occurrence, and is found in the experience of the Association to be quite adequate. *See here reply to question No. 8.*

No. 11. "*Upon what do you rely for Safety?*"—Upon competent periodical inspection. *See reply to questions 8 and 10.*

No. 12. "*Low-Water Detectors.*"—We recommend that each boiler should have two good glass water-gauges, fixed directly to the front end plate of the boiler, immediately under the eye of the attendant. We approve of a low-water safety-valve, which relieves the pressure of the steam as soon as the water falls below the desired level. Alarm-whistles may be easily silenced, and, as a rule, have been discarded. A low-water safety-valve is more reliable, as it blows off either for high steam or low water, and thus is kept in constant play.

No. 13. "*Automatic Feed-Regulators.*"—We do not approve of these, thinking them apt to mislead, and to engender a false confidence; we prefer feeding by hand as more trustworthy.

No. 14. "*Testing Boilers in Use by Hydrostatic Pressure.*"—We do not adopt this course as a rule, and only adopt it when there is some peculiarity in form, say to ascertain the strength of a flat surface, or when any question arises as to the power of a furnace tube to resist collapse. In the case of the cylindrical shells of boilers, we rely on careful inspection. If the plates appear to be washed, we drill them to ascertain the precise thickness, and sound the rivet-heads to see if corrosion is interfering with the consistency of the metal. We have the boiler so set that all parts may be accessible to examination. If the brick-work interferes we have it removed. When hydraulic tests are applied, the boilers are gauged at the flat ends, and also in the furnace tubes, to see if any movement occurs. We have no faith in blind hydraulic tests for getting at the strength of parts out of sight. Our rule is to see everything.

No. 15. "*The Experience and Approved Usages of other Similar Associations in England.*"—The object of the Manchester Steam Users' Association is the saving of human life and the prevention of explosions. It has no shareholders, and pays no dividends. The President and members of the Executive Committee give their time gratuitously year after year in the interest of the members and the public generally, with the object, as already stated, of saving life. There is no other similar association in the country, but there are joint stock boiler insurance companies founded for the purpose of dividend.

No. 16. "*The Degree in which the System of compounding has taken the Place of Expansion in the Single Cylinder in the Manufacturing Districts of England, and what are the Views of leading Steam-Engine Builders as to the Relative Advantages of the Two Systems, so far as known to you?*"—Practically speaking the "compound" system is more generally adopted than the "simple," or single cylinder system; still, the simple system has its advocates, and the question is still a vexed one as to which of these two systems is the better, but for high pressure there is no doubt that the "compound" system is in more general favor.

No. 17. "*In what Degree Direct-Acting Engines are coming to supersede the Beam-Engine?*"—Direct-acting engines are almost entirely superseding beam-engines, more especially for high pressures. It is a very general system to lay two horizontal systems side by side

and place the cranks at right angles, arranging one cylinder to be the high pressure one, and exhausting into the other, which is the condensing one. With this arrangement but one condenser and one air-pump are required. A steam reservoir is sometimes placed between the two cylinders, but not always. The plan of regulating the cut-off in high-pressure cylinders by the governor is coming increasingly into favor. Sometimes new high-pressure beam-engines are laid down on the McNaught principle. This, however, is rarely done. Many beam-engines are compounded with a horizontal high-pressure cylinder.

I think I have now replied to all the questions contained in Mr. Porter's letter, but may add that our Association goes to the expense of sending a qualified officer to investigate every explosion that occurs in any part of the country, and draw up a full report with illustrative drawings of the same. These are carefully preserved at these offices, and form most instructive and valuable documents. A very abridged statement of the description of boiler, course of the rents, effects of the explosion, and the cause is given in a tabular synopsis published in the Association's printed monthly reports, circulated among the members and sent to the press gratuitously, so as to disseminate the information as widely as possible. See report for December, 1875, inclosed herewith. Sometimes these monthly reports are made the vehicle for conveying suggestions on compoundings, etc. See report for December, 1874, inclosed herewith. I also inclose a synopsis, which gives the rules of the Association, with further information as to rates, membership, visits of inspectors, etc.

The Association has boilers enrolled under its inspection situated in all parts of the United Kingdom; also it has several corresponding members abroad, and is affiliated with another institution for the periodical inspection of boilers at Calcutta. Its monthly reports will be found in the Library of the Franklin Institute at Philadelphia.

Trusting that this information will be of service to you, and wishing you every success in your labors,

I remain, gentlemen,

Yours faithfully,

L. E. FLETCHER,
Chief Engineer.

INJECTORS.

About the year 1858-59, Mr. Giffard, of France, produced his now well-known injector, or continuous boiler-feeder. In this instrument a jet of steam from the boiler is made to draw in a quantity of water, and force that water into the same boiler against its own pressure, or even to force it into another boiler carrying steam at a higher pressure. This striking invention was for a time classed among mechanical paradoxes, but familiarity with it, as with other notable inventions, which seemed very astonishing at first, has dissipated the charm that hung about its novelty. Some look upon it as a beautiful illustration of the correctness of the laws of physics which govern it, while others care little how it does work,—accepting its operation as a fact. To our Centennial Exhibition we naturally look for information as to what improvements, if any, have been made in inventions of this character when transplanted into a new soil. Few inventions from abroad retain long, in a new land, all the characteristics of the

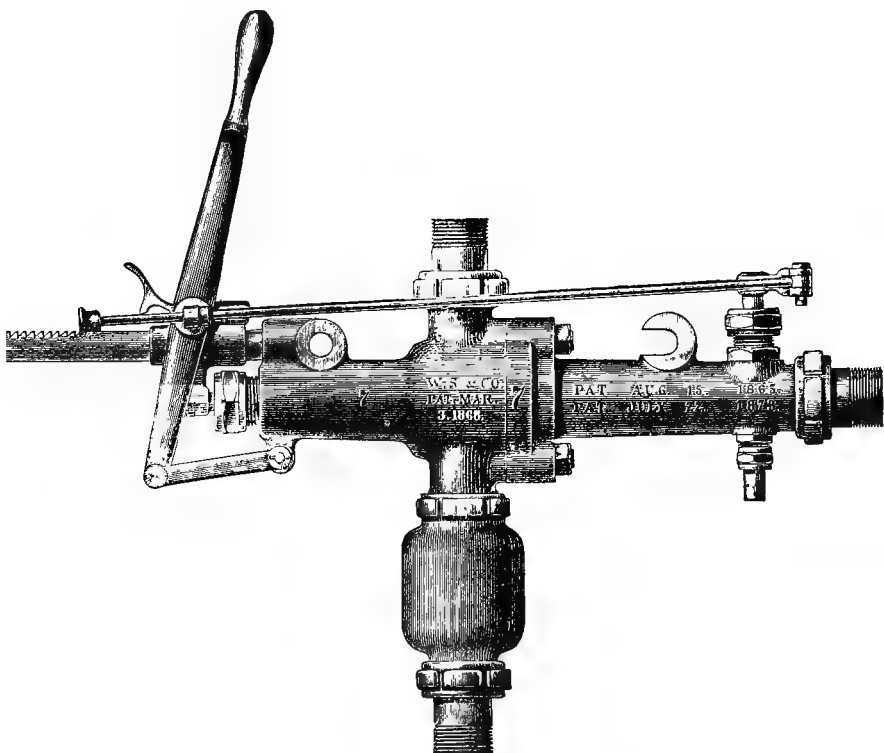
original; the modes and methods of the country must modify all engineering structures, no matter how small or how simple in detail. This particular invention was one that attracted attention from its beginning. It was almost immediately taken up in England, and soon after in the United States.

The introduction of the Giffard injector in this country was made by William Sellers & Co., of Philadelphia, in 1860, and they were, during the continuance of the original patent, the sole licensees and manufacturers under that patent in the United States, and have made, from time to time, improvements in the instrument. In 1865 they introduced the novel and important principle of self-adjustment. Previous to this injectors had either fixed nozzles or were arranged with independently adjustable nozzles, separately operated to adapt the steam- and water-supply to each other, and to the changes in the boiler pressure, etc. In these injectors any want of proper adjustment was indicated either by a waste of water or in-draft of air at the overflow, and if, after a most careful adjustment of the parts to produce the best results, the steam pressure in the boiler changed, the instrument would work badly until readjusted for the new conditions. The self-adjusting instruments have no waste at the overflow. After starting, the steam-supply alone is adjusted by hand, and the water-supply is automatically regulated, so that the steam is always combined with the exact quantity of water necessary to produce the best results, no matter how much the steam pressure in the boiler may vary. This instrument in its improved form went through various changes for the better up to the year 1876, when a new style, the "Injector of 1876," was exhibited at the Centennial, after careful tests on leading railroads.

The advantages of using an injector to feed the boiler of a locomotive are that it may be operated to deliver the water in a continuous stream, either when the engine is at rest or in motion, and it furnishes heated water at all times, even when the tank has been freshly filled. To obtain the full advantage of the injector when the locomotive is running regularly, the manipulations of the instrument required to start and regulate the feed should be simpler than those necessary in the use of the pump. The "Injector of 1876," exterior and sectional views of which are shown in Figs. 48 and 49 respectively, was designed to accomplish this object, and is put in operation and regulated entirely by moving a single handle, H. The connection to the boiler, and those for the admission of steam and water, are clearly designated in print in Fig. 49, the latter being provided with a suction-chamber to steady the flow. A is a fixed receiving-tube through

which the principal jet of steam passes, being regulated by the position of the interior conical spindle. The annular jet of steam combines with water in the combining-tube C, and the concentrated jet is forced through a delivery-tube D, and the check-valve shown, to the boiler. The combining-tube C forms part of the piston N, N, which fits freely into the case, and the smaller end of the com-

FIG. 48.



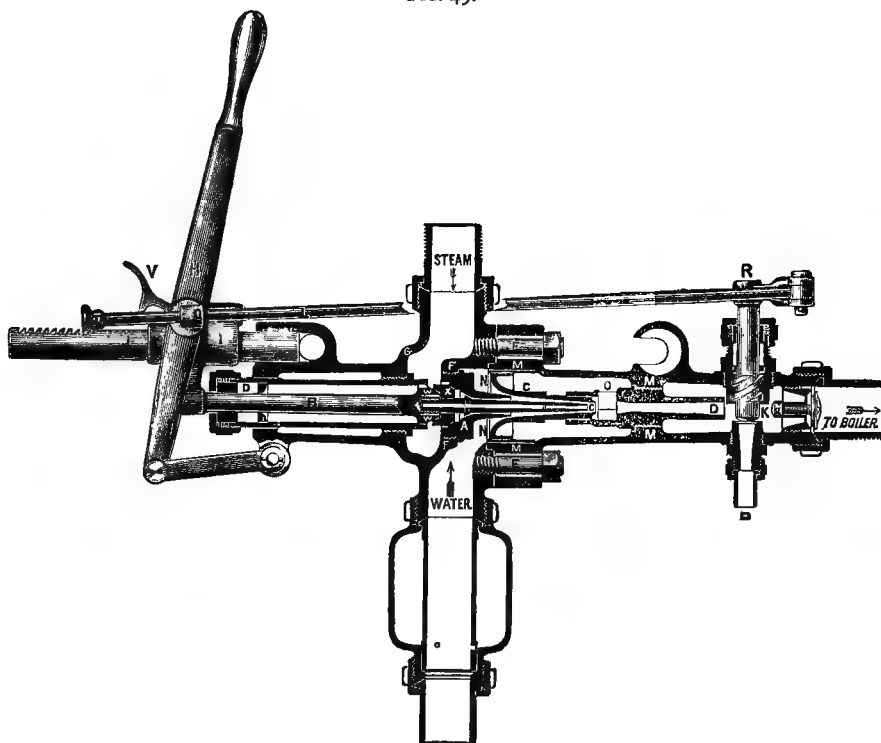
External View of the Sellers "Injector of 1876."

binning-tube slides freely also in the end of the delivery-tube D. The pressure of the water is on one side of the piston N, N, and the other side is in communication with the jet issuing from the combining-tube through an opening O, inside of the delivery-tube. If the water-supply be too great, a portion escapes through the opening O, and, accumulating in the surrounding chamber, forces the piston and combining-tube toward the receiving-tube, and contracts the annular space between the two latter, so that the water-supply is reduced. If the water-supply be insufficient, a partial vacuum will be produced in the

chamber, and the piston moved to admit more water. In this manner the supply of water is automatically adjusted to suit all requirements.

The description thus far is common to all the Sellers self-regulating injectors. In the "Injector of 1876," the central spindle shown in the receiving- and combining-tubes is secured to an operating-

FIG. 49.



Sectional View of the Sellers "Injector of 1876."

spindle B, and has a small bore throughout its length, which receives steam through small openings, when the valve W, on the operating-spindle, is raised from its seat in the top of the larger valve X, which admits steam to the receiving-tube around the central conical spindle. The operating-spindle is moved, through the arm and slide shown, by the operating-lever H, and the latter, by means of the rod L, with stops upon it, operates the screw overflow-valve on the stem R. In the position shown, steam is shut off, and the overflow-valve is open. Upon moving the lever the valve W is first opened, and steam

is admitted to the small bore of the central spindle, and issues in a jet, which induces a current in the water-supply pipe, whereby the air is withdrawn, water lifted and expelled at the overflow. [The lifting effect desired is quite dissimilar from the action of the annular jet in operation as a boiler-feeder, being more nearly allied to the action of the exhaust in producing a draft in the smoke-pipe of a locomotive, and requires a high velocity and free expansion at the moment of escape.] When the water is lifted, by moving the handle H still more, a collar on the central spindle comes in contact with, and opens, the large valve X, thereby admitting steam to the annular jet to produce regular operation, as previously described, and the handle, upon being moved back to its extreme position, strikes the stop T on the rod L, and thereby shuts the overflow. At the same time a pawl, V, drops into a rack on the arm J, and holds the lever H in position when the latter is pushed in to regulate the flow. This pawl is lifted and caught fast, when the lever is pushed entirely in to stop the injector, and not relieved again till the lever is at the other extreme, as above explained. The instrument can be located in any convenient position on a locomotive above the water-level in the tank, as it is considered advantageous to have the injector lift its supply of water.

In addition to the feature of improvement to secure convenience of manipulation, the efficiency of the instruments has been materially increased in several important particulars. The members of the group who specially reported on injectors did not find it possible, as requested by Messrs. William Sellers & Co., to undertake elaborate tests with injectors, but from the results of numerous experiments made by that firm as a basis for initiating improvements and making guarantees of performance, the writer has made several selections, which are hereafter presented.

On a locomotive, economy is secured by utilizing surplus steam to heat the water in the tender, and the hotter the water the injector will feed, the greater is its practical utility as a boiler-feeder. In using the "Injector of 1876," no difficulty can be observed in starting after steam has been blown back through it to heat the water in the tank. The quantity of water that can be made to pass through any given-sized opening, arranged on the conditions which obtain in all injectors, depends upon two conditions, viz., the pressure of the steam and the temperature of the feed- or supply-water. The colder the latter, the hotter may be the steam used to inject it, and *vice versa*; so that any improvement in an instrument that will enable it to approximate the theoretically possible combination of temperatures of steam

and water is of great importance. The improvements made in this respect are shown by the following table :

STEAM PRESSURE.	ADMISSIBLE TEMPERATURE OF FEED.	
	Old-style Injector.	Injector of 1876.
Pounds.	Degrees Fahrenheit.	Degrees Fahrenheit.
10	148	.....
20	138	138
30	130	.....
40	124	135
50	120	.....
60	.....	130
80	.....	130
100	110	132
120	90	133
150	.....	128

If this result were obtained by any sacrifice of range of the instrument, it is doubtful whether it would be advantageous to employ it. The limit of range of any injector is in a degree dependent upon the temperature of the feed-water ; but it is claimed for the new instrument that it works through a greater range with varying conditions of temperature of feed than any instrument yet made. The relative ranges for several injectors, found by experiment, are shown in the following table, the maximum delivery in cubic feet or other unit of measure being called 100 units :

	MAXIMUM DELIVERY.	MINIMUM DELIVERY.	RANGE.
	Units.	Units.	Per Cent.
Giffard adjustable.....	100	60	40
Sellers self-adjusting.....	100	50	50
“ Injector of 1876....	100	40	60

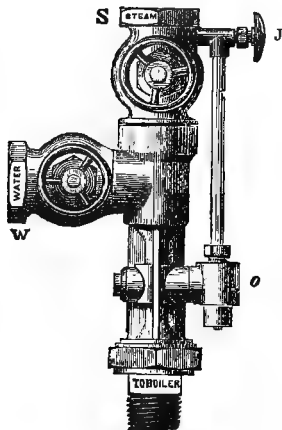
Experiments further show, in addition to the increased original temperature of water which the injector will receive, and the increased range between maximum and minimum deliveries, that the new instrument, in common with the other self-adjusting instruments, has a higher maximum than the original Giffard adjustable injector. For the purpose of comparison, the writer has selected the following from the tables of capacity furnished to enable purchasers to select instruments of proper size. The term No. 6 signifies that the minimum diameter of the delivery-tube is 6 millimetres.

STEAM PRESSURE.			CUBIC FEET OF WATER DISCHARGED PER HOUR.		
Pounds.			No. 6. Giffard.		
			No. 6. Self-adjusting.		
10	46.5	83.5	90	108.5	140.4
20	58.0	90.6	100	113.9	147.6
30	67.5	97.7	110	119.1	154.7
40	76	104.8	120	124.0	161.8
50	83.5	112.0	130	128.7	169.0
60	90.3	119.1	140	133.3	176.1
70	96.7	126.2	150	137.5	183.2
80	102.8	133.3			

The No. 7 Giffard injector, one size larger than the example above, discharges at 120 pounds a pressure of 169.3 cubic feet. The No. 6, self-adjusting, as above, discharges 161.8 cubic feet, so, at the maximum, the capacities of the new instruments are practically the same as those of the original Giffard instruments respectively one size or number larger.

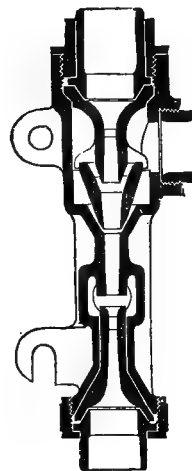
Messrs. Nathan & Dreyfus, of New York, exhibited the Friedman injector in various forms. This instrument is the invention of Mr.

FIG. 50.



External View of Friedman Injector.

FIG. 51.



Sectional View of Friedman Injector.

Alexander Friedman, of Austria, and was introduced in the United States by the exhibitors, who have added some improvements. An external view of the instrument is shown in Fig. 50, and a longitudinal section in Fig. 51. The steam enters at the upper end, passes in a jet

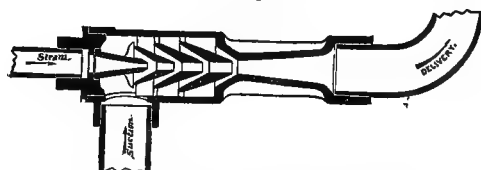
through the receiving-tube, and, combining with a first supply of water in the conical intermediate combining-tube, the jet issues from the latter with sufficient velocity to induce and combine with a second current of water from the annular space below, when the concentrated jet is forced across the overflow-chamber to the boiler in the usual way. For lifting the water, an independent small jet is provided in the tube shown at the side in Fig. 50. This tube and jet are omitted in "non-lifting" injectors. The operations necessary to start the lifting injector and regulate the flow are shown by the following extract from the manufacturers' circular:

*"To Start :—*Be sure the water-valve or cock W is open, then open the small jet-valve J (with low pressure full, with high pressure partly) until the water flows out of the overflow at O. (This is the lifting operation.) As soon as this water appears at the overflow, open the main steam-valve S gradually, and close the small jet-valve. Should water still be discharged from the overflow, as may be the case where the steam pressure is low, reduce gradually the water-supply until the water ceases. *To Stop :—*Close the main steam-valve."

This instrument is remarkably simple, and it is to be regretted that its efficiency in comparison with other forms of injectors has not been authoritatively established. The capacity of a No. 6 injector in gallons per hour is given in the exhibitors' circular as follows: steam pressure 120 pounds, capacity per hour 870 gallons; steam pressure 80 pounds—720 gallons; steam pressure 63 pounds—570 gallons; steam pressure 20 pounds—360 gallons. The circular states also that the maximum temperature at which the injector will operate is 140°.

The same firm also exhibited ejectors for raising water and conveying liquids, the construction of which is shown in Fig. 52. In this case

FIG. 52.



Sectional View of Nathan & Dreyfus Ejector.

the high velocity of the original small jet is reduced and utilized by combination with volumes of water successively drawn in by the induced currents at the several openings.

Air and gas exhausters resembling in construction the ejector last described, were exhibited by Messrs. Shutte & Goehring, of Philadel-

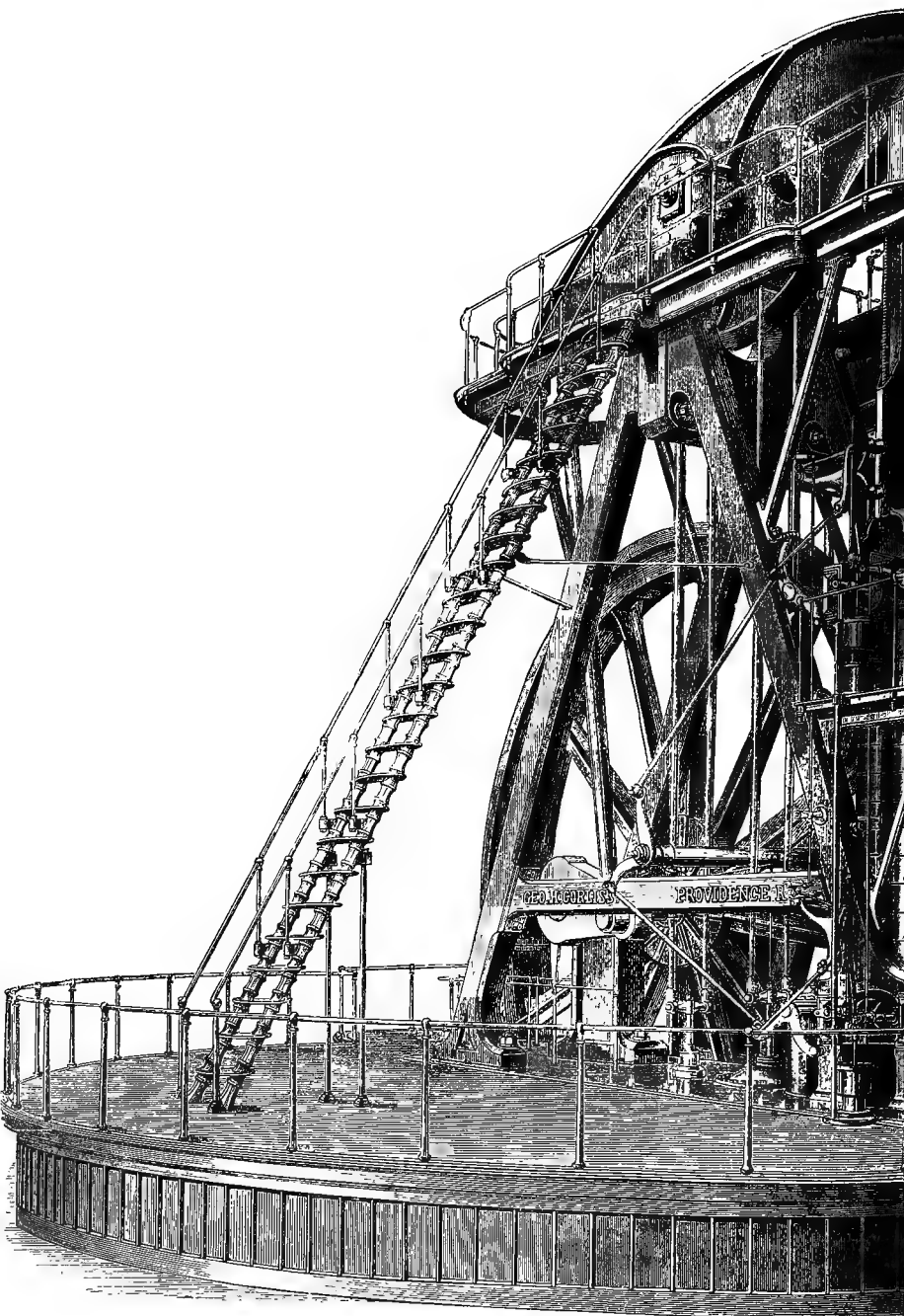
phia. The advantages of such a system for use when the steam pressure is in excess of that to be overcome are evident, as the original high velocities are utilized in putting successively in motion increased volumes. It is desirable, however, to know whether there is such a surplus of velocity with ejectors acting under pressure as to make it comparatively economical to employ the system, even to the extent of a duplicate water-supply. In this connection it may be stated that there have appeared, simultaneously apparently, both in Europe and the United States, but by different inventors, injectors in which the steam-jet instead of the water-supply is duplicated; one jet forcing water to the second, which delivers it at the higher final pressure and velocity. Experiments would be of great interest, showing the advantages, if any, to be derived from either of these two contrary methods of operation as compared with the single steam- and water-jet of the original Giffard injector with modern improvements.

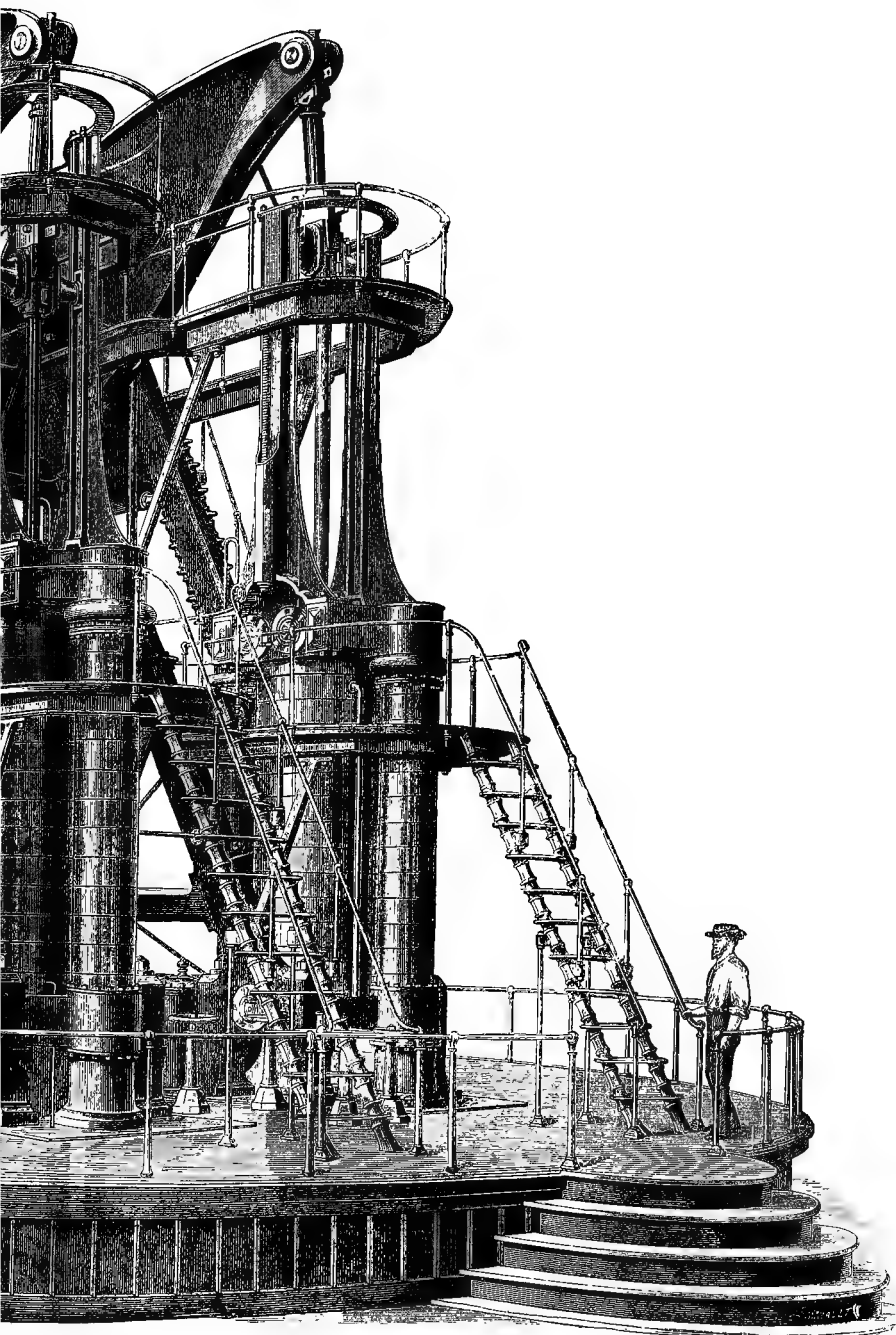
The duty of an injector when used simply for lifting water is very low. From some experiments made by the writer in 1865* with a small Giffard injector delivering 20 cubic feet per hour, using steam varying for the several experiments from 61 to 70 pounds, and water pressure varying from 40 to 76 pounds, it was found that the injector delivered under different relations of pressure and adjustment from 13 to 17 times the weight of steam required to operate it. In 1869, Mr. John Bourne published some similar experiments† with an injector of 3 times the capacity of that mentioned above, using a steam pressure of from 30 to 40 pounds, and water pressure as high occasionally as 90 pounds, from which it appears that several of the experiments showed a delivery of from 16 to 20 times the weight of steam used. The best result was a delivery against a pressure of 90 pounds of 16 times the weight of steam used, which is equivalent to lifting 16 pounds of water about 207 feet high for each pound of steam used, or to 3312 foot-pounds. On the basis that a moderate-sized steam-pump may require 60 pounds weight of steam per horse-power per hour, or one pound for each 33,000 foot-pounds of work, the duty of the injector for simply lifting water appears to be about $\frac{1}{10}$ of that of a steam-pump.‡ This simply shows that it is doubtful whether any injector can be economically used for lifting fluids in competition with pumps, except in cases where it is desirable to raise the temperature of the fluid at the same time. In an injector little of the heat of the steam is expended in work, but the remainder goes to raise the tem-

* See *Journal Franklin Institute*, January, 1866.

† Appendix, *Steam-, Air-, and Gas-Engines*, by John Bourne.

‡ For small steam-pumps the ratio would be $\frac{1}{3}$. (See close of article on *Steam-Pumps*.)





ENGINES.

perature of the fluid operated upon, and in feeding the boiler is entirely utilized. For boiler-feeding, then, the injector is more economical than the pump, except in cases where the feed-water can be heated by waste steam to a considerably higher temperature than the injector will receive it.

STEAM-ENGINES.

THE CORLISS ENGINES.

The main lines of shafting in Machinery Hall, referred to under the head of "Transmission of Power," were all operated by a pair of beam-engines, located at the junction of the transept with the south nave. These engines, from their great size and original design, formed by far the most prominent exhibit in the building, and received much attention from engineers, the public, and the press. Mr. George H. Corliss, of Providence, Rhode Island, the inventor and manufacturer, provided the engines and boilers, and also furnished and put in all the foundations for the machinery, and supplied all the connecting-pipes, with the shafts and all the appurtenances connected with the transmission of power from the engine to the nine main belts.

Mr. Corliss, being a member of the Centennial Commission and of the Executive Committee, would not allow his exhibits to be entered for competition, and, consequently, under the rules adopted by the Commission, they did not come before the Judges for examination and report. For future reference, a plate is presented (Fig. 53) showing a large perspective view of the engines, in connection with the following brief description of the engines and boilers.

There were two condensing beam-engines, which were proportioned to work expansively, with a steam-pressure of 80 pounds. The valves and valve-gear were of the style peculiar to Mr. Corliss, with several improvements specially designed for, and first applied to, these engines. The cylinders were each 40 inches in diameter, with 10-foot stroke of piston. The beams were 27 feet long by 9 feet deep, and weighed 11 tons each. The engines were connected at right angles to a main shaft carrying the fly-wheel, which was a cut gear-wheel, 30 feet in diameter, with a face width of 2 feet, and a weight of 56 tons, and is believed to be the heaviest cut-wheel ever made. It geared with a pinion 10 feet in diameter, on a main line of underground-shafting 256 feet long, running across the building. This

line of shafting was connected by bevel-gears, 6 feet in diameter, at each end, and at two intermediate points with shafts, running longitudinally of the building, from which belts were run up through the floor to eight lines of overhead shafting, each having a length of 658 feet. The main shaft was also continued southerly 100 feet under the floor of the transept to operate a line of shafting in the Pump Annex.

The fly-wheel made 36 revolutions per minute, giving a piston speed of 720 feet per minute. The gears were cut by machinery devised and constructed for the purpose by Mr. Corliss, and ran with remarkable smoothness of motion and freedom from noise, notwithstanding the fact that the peripheral velocity of the spur-gears was 3384 feet per minute, or about 38 miles per hour. Some of the most delicate machinery operated by exhibitors, such as that of the Waltham Watch Manufacturing Company, was conducted on the floor over the bevel-gearing.

The engines were rated at 1400 horse-power, which could be increased to 2000 horse-power when required. They operated without appreciable vibration, and no stoppage was made on account of hot bearings or any derangement of any part of the machinery. The cylinders were jacketed with live steam, and were kept hot continuously from the hour of opening, May 10, till the formal closing on November 10.

There were twenty vertical boilers furnished by Mr. Corliss, which were erected in a separate building. A portion of them supplied steam to the main engines above described, the others were sometimes used to supplement the steam-supply to the Pump Annex. Each boiler contained 48 tubes, 3 inches in diameter, in a shell 4 feet in diameter and 14 feet high. The aggregate heating surface in the 20 boilers was reported to be 13,000 square feet.

The material of the above exhibit, on its re-transportation from the Exhibition to Providence, loaded 71 cars, the aggregate weight being upward of 776 tons.

STATIONARY AND PORTABLE ENGINES.

For reasons previously mentioned, no attempt will be made to describe the distinguishing features of the large number of stationary and portable engines exhibited. A few have, however, been selected to illustrate the application of different types of valve-gear.

Engines regulated by the action of the governor on a throttle-valve operate under two important disadvantages: first, the regulation is not perfect, no matter how good the governor, for the reason that there must necessarily be considerable space between the throttle and main valves, which tends to retard the regulation by furnishing an additional supply of steam when the throttle is closing and absorbing a portion of the steam supplied as the throttle is opening; second, the initial pressure in the cylinder is diminished, which reduces the economy, as is well understood and shown by experiments referred to hereafter; the system, moreover, does not enable the benefits due to free expansion to be utilized.

The principal improvements which caused the high degree of efficiency of modern steam-engines for manufacturing purposes were initiated in the year 1849, by Mr. George H. Corliss, of Providence, Rhode Island, by the invention of his well-known cut-off, tripped automatically by the action of the governor so as to proportion accurately the supply of steam to the load to be overcome, and at the same time utilize, in the cylinder, substantially the full boiler pressure and expansive effect of the steam, and thereby secure economy in the use of steam and fuel.

The segmental valves, adopted by Mr. Corliss and known by his name, secured also the further economy due to the reduction of the area in cylinder passages to a minimum. The arrangement of the exhaust valves in the bottom of the cylinder secured still another advantage, which, strange to say, is not appreciated by all manufacturers—that the cylinder is not only cleared of water in starting, but, in regular working, a free exhaust in such position carries out most of the moisture in the steam due to the performance of work in the cylinder, and there is less to be re-evaporated by radiation from the walls of the cylinder which must be re-supplied during the next stroke, at the expense of the fuel. The success attending the improved mechanism of Mr. Corliss, and the business manner in which it was introduced, naturally gave an impetus to invention on the subject, and many engines with governor cut-offs were developed, though but few obtained a standing in the market. The main valves or independent cut-off valves were operated by cams, revolving eccentrics, and secondary

steam-cylinders, and many modifications of the trip cut-off were designed, but the latter did not go into general use while the original Corliss patent was in force.

Mr. P. Van den Kerchove, of Ghent, Belgium, exhibited Corliss and Rider engines of excellent design and finish. The former was of 160 horse-power, and was made for the Belgian mint.

The Rider engine is so named from the cut-off, which is an American invention, represented by Messrs. C. H. Delamater & Co., of New York. In these engines, a double main slide-valve is used with a concave semi-cylindrical cut-off valve-seat on the top. The main valve has steam-ports through the ends, which, being twisted as they rise, issue through the cut-off valve-seat on spiral lines, of reverse pitch, at the two ends of the valve. The cut-off valve is a cylinder with corresponding spiral ends, and receives a positive longitudinal motion from an eccentric. The cut-off is adjusted by simply revolving the valve partially, thus causing different portions of the spiral-ended cylinder to close the cut-off ports and thereby suppress the steam at different parts of the stroke. No balancing arrangement is used, and none is needed, as the longitudinal motion is comparatively large, and is resolved with the lateral force applied through an arm from the governor, so that the motion of the valve over its seat is diverted from a right line to a long spiral. When the engine is in motion the cut-off valve can be turned by applying the hand to the valve-stem, and, as might be expected, the engine is under full control of the governor.

The engine which operated most of the machinery in Agricultural Hall was furnished by Mr. Jerome Wheelock, of Worcester, Massachusetts. Side and sectional views of the cylinder are shown in Figs. 54 and 55. There is one main and one cut-off valve of the segmental type provided for each end of the cylinder, exterior views of which are shown in Figs. 56 and 57. Each main valve has an exhaust-cavity, and operates in the same manner as an ordinary slide-valve. The cut-off valve regulates the supply to the small steam-chest containing the main valve, and as the latter never communicates with the exhaust, slight leaks of the cut-off valve do not appreciably affect the economy. The valves are made a little conical, and are each provided with a steel bush to run on a stationary pin secured to one of the bonnets. To the smaller end of the valve is secured a hardened steel stem, which runs through a steel bushing in the other bonnet, and the shoulder on the stem bears against the steel bushing making a steam-tight joint at the points B in the cuts, and no packing is required for the valve-stem. The steel bush is so adjusted that the

WHEELOCK ENGINE, EXTERNAL VIEW OF CYLINDER AND VALVE-GEAR.

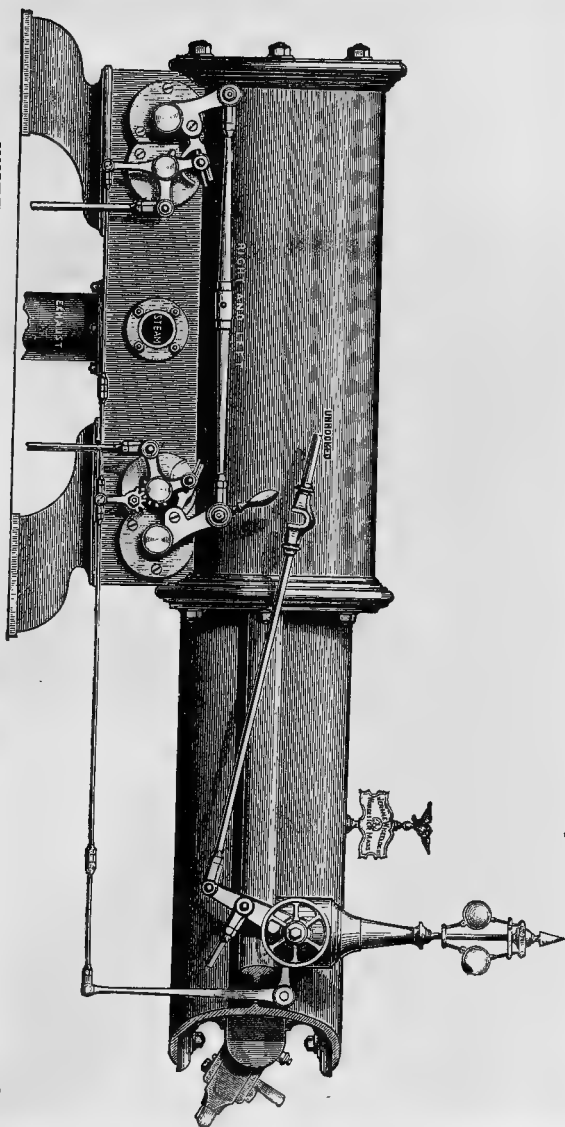
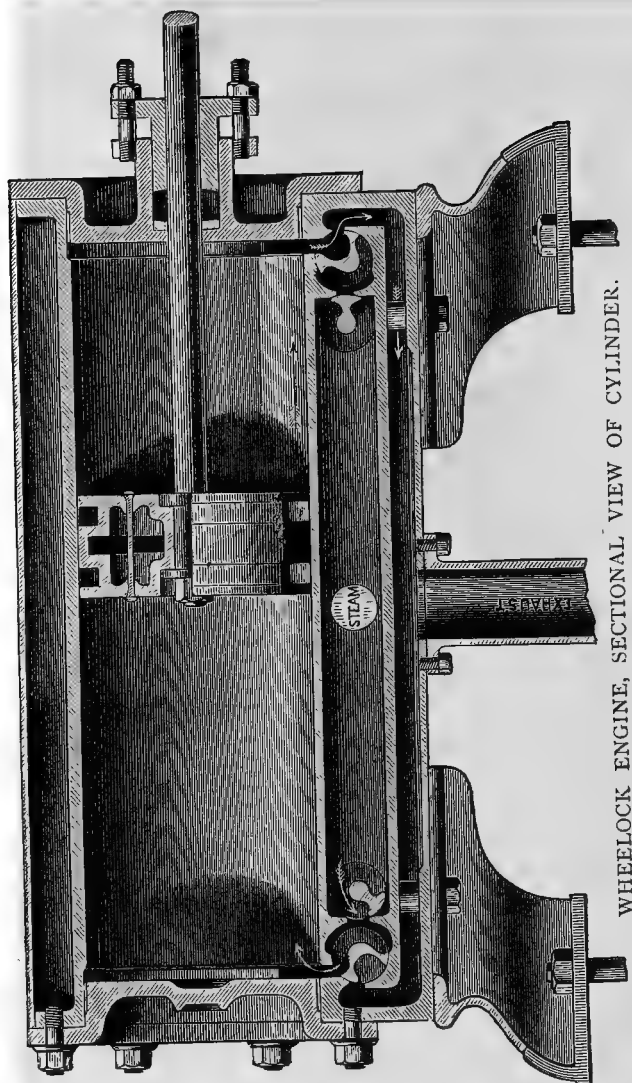


FIG. 54.

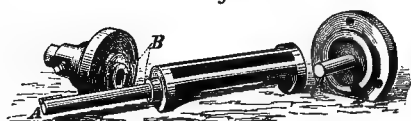
FIG. 55.



WHEELOCK ENGINE, SECTIONAL VIEW OF CYLINDER.

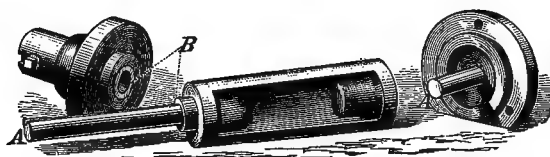
valves are pushed back from their seats sufficiently to transfer the wear to the steel bearings and yet maintain steam-tight joints between the valves and seats. Valves were shown which had been in use for a long period, on which the surfaces were highly polished, indicating that they had been steam-tight, and there was no perceptible wear on the bearings. As shown in Fig. 54, motion is originally applied to the main valves, and pawls from their operating arms drive the cut-off valves, the pawls being released by cams carried on the cut-off

FIG. 56.



Wheelock Engine, Main Valve.

FIG. 57.

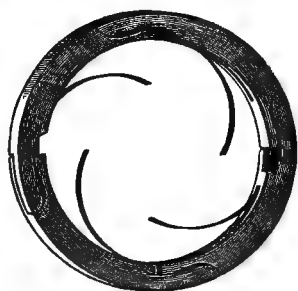


Wheelock Engine, Cut-off Valve.

valve-stems, which are adjusted by the governor through the gears, arms, and links, shown. The valves are closed by weights checked by dash-pots.

Fig. 58 represents the Wheelock steam packing, which is made in segments with a finger formed on one end of each to enter a corresponding cavity in the adjoining end of the next, as shown. Two such rings are provided and placed in grooves in a skeleton piston, a section of which is represented in Fig. 55. These pistons are simple and light, and operate very satisfactorily.

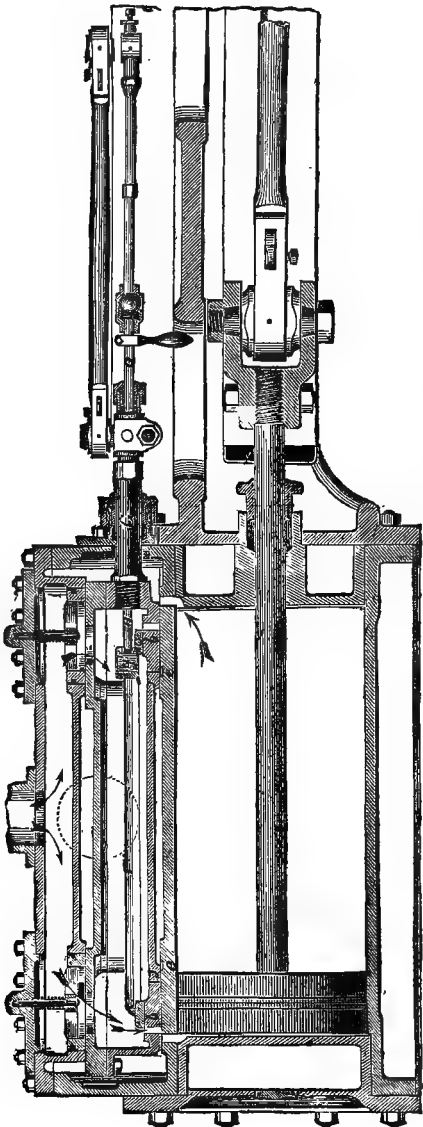
FIG. 58.



Wheelock Steam Packing.

An engine exhibited by the Buckeye Engine Company, of Salem, Ohio, contained a number of remarkable and ingenious features. As shown in section, in Fig. 59, the main valve is box-shaped, and slides between the valve-seat on one side, and balancing pistons communicating with a chamber in the steam-chest cover on the other. Steam is admitted through this chamber and the balancing pistons to the inside of the valve, and the exhaust escapes at the ends of the valves to the space surrounding

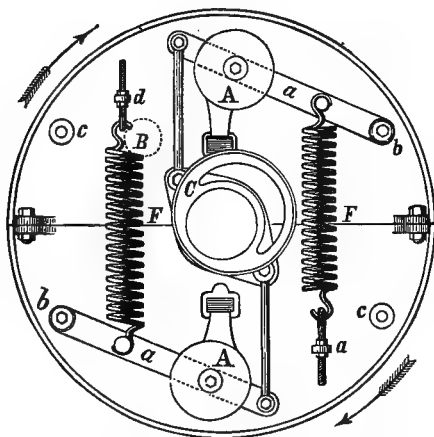
FIG. 59.



“BUCKEYE” ENGINE, SECTION OF CYLINDER AND STEAM-CHEST

it. The cut-off valves are simple connected plates arranged to slide upon a valve-seat inside the main valve, as shown, and are operated by a stem running through the main valve-stem. The cut-off valve-stem is operated by an eccentric on the main shaft, which is advanced or retracted angularly, to vary the cut-off, by a governor arranged within a pulley on the main shaft and revolving therewith, details of which are shown in Fig. 60. Two levers *a, a*, pivoted at *b, b*, carry weights A, A, which, by centrifugal force, when the engine is in

FIG. 60.



Governor of "Buckeye" Engine.

motion, tend to move outward and overcome the resistance of springs F, F. The ends of the levers are attached to lugs on the eccentric, as shown. The fact that the cut-off valves are unbalanced should apparently render the governor unsteady in its action; but the friction of the valve is part of the resistance to be overcome by the centrifugal force and acts in the same direction as the springs; and sufficient mass being provided to prevent extreme movements, from the regular variations of resistance due to the closing of the valve at each end of the stroke, and the average resistance being practically uniform, it appears as a fact that the engine is under the full control of the governor, and the indicator diagrams are remarkably perfect in appearance.

A governor similarly arranged on the main shaft was applied to adjust the main valve of the Hoadley portable engine, and is described and illustrated in the report of the trial of that engine hereto appended.

Mr. Wm. Wright, now of Newburg, New York, at an early date

designed a number of cut-offs, varied by the governor, in which, generally, horizontal poppet-valves were used, operated by a cam on a shaft geared to the main shaft; the adjustment of the cut-off being made by shifting position of the rear of the cam in various ways. In several modifications by Mr. Wright and others, the poppet-valves were arranged vertically, and in certain cases slide-valves in similar position were substituted, the valves of either kind being tripped to drop freely or lowered by an adjustable cam. Engines showing different applications of these features were exhibited by the Hartford Foundry & Machine Company, and by Messrs. C. W. Brown & Co., of Fitchburg, Massachusetts. The engine last named operated most of the machinery in the Saw-Mill.

A pair of horizontal stationary engines of the compound intermediate receiver type were exhibited, also an engine in which the cut-off was regulated by an ingenious modification of link-motion, the details of which are not at hand. A large number of stationary engines of various sizes were shown with valve-gear of the ordinary types.

The Wells Balance Engine Company, of New York, exhibited an engine with two pistons in the same cylinder. There were triple cranks, of which the centre one was opposite the other two. The nearest piston connected in the usual way to the central crank, the farther piston connected, by two rods running through the other piston and front cylinder-cover, with a pair of connecting-rods running to the outer cranks. A single slide-valve distributed steam alternately between the two pistons and by a forked port to both ends of the cylinder. This engine being almost perfectly balanced was run at a high rate of speed, and developed very great power in proportion to its size and the space occupied.

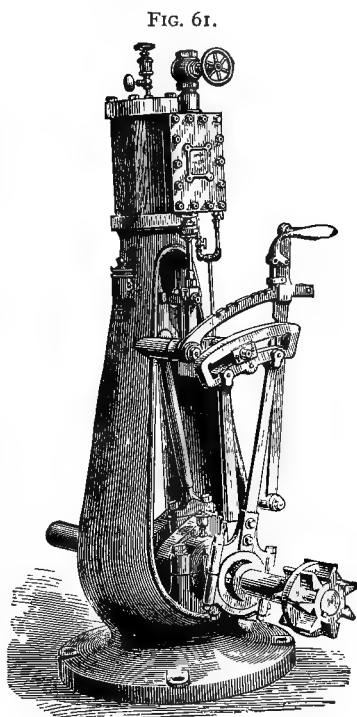
No high-speed engine of large size with details especially designed to secure economy of fuel, as in the Porter engine, at the Paris Exhibition, was exhibited, though the speed of some of the engines shown was higher than the usual practice, and the indications were that higher speeds were considered desirable. All new trains in rolling-mills are now operated by engines directly connected with the rolls, and marine engines of the largest size have, for a considerable time, been run at the full speed of the propeller shafts. The advantages of high speed are that the inequalities of pressure in the cylinder due to the expansion of steam are distributed throughout the stroke, great smoothness of working is obtained, and engines of less size are required for a given power.* To secure these advantages, however,

* See *A Treatise on the Richards Steam-Engine Indicator*, by Mr. Charles T. Porter.

with large engines requires the use of proper details of construction.

The New York Safety Steam-Power Company, of New York City, exhibited a number of vertical engines of different sizes, designed to run at a high speed, for use in small steamers or manufactories. An illustration of one of the company's 10 horse-power launch engines is shown in Fig. 61. For stationary use, the link-motion is omitted. These engines are constructed on the modern system of interchangeable parts, made accurately to gauge, as developed in gun and sewing-machine manufacture. The design is pleasing, and has been closely imitated by other builders.

The portable engines exhibited by the Baxter Steam-Engine Company, of New York, were also built with interchangeable parts by the Colt's Arms Company, of Hartford, Connecticut. These engines were used to operate the machinery in the Glass-House, the Nevada State Building, and in other locations. Portable engines of excellent design were also exhibited by Messrs. Shapley & Wells, Binghamton, New York, and other exhibitors. A report of the trial of the Hoadley portable engine by a committee of the Group is hereto appended.



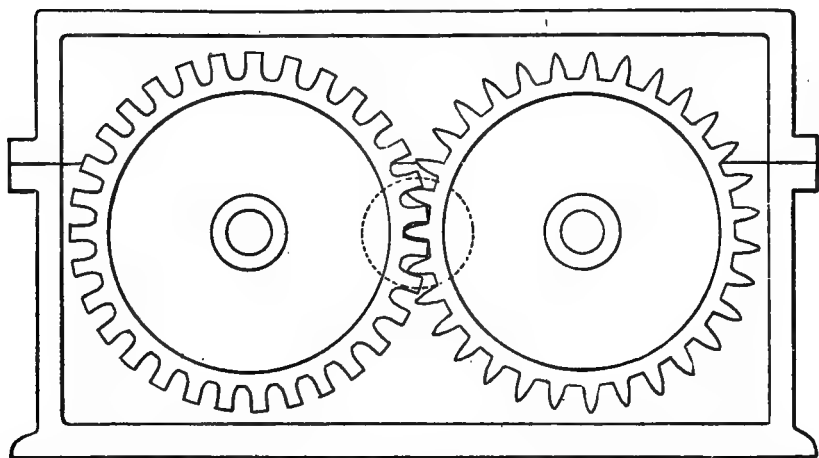
Launch Engine, New York Safety
Steam-Power Company.

ROTARY ENGINES.

It may be safely stated that experienced engineers have little faith in rotary engines of the well-known type for the economical development of power. Much ingenuity has been expended upon the subject, but the difficulties of obtaining tight wearing surfaces are apparently insuperable. Such engines, however, offer advantages on account of their compactness and simplicity when economy of steam is of secondary importance. For instance, a small hoisting-engine used but little

may as well be of this character, since, considering first cost and reliability under conditions of neglect, in connection with the quantities of steam used, it may prove more economical in the end than other forms. The rotary fire-engines illustrated in the fire-engine report, presented herewith, are also well adapted to their work, and have advantages peculiarly their own. A number of rotary engines of different forms were exhibited, but the only one believed to possess novel as well as exceptional features was that invented and exhibited by Richard Dudgeon, New York, a longitudinal section of which is shown in Fig. 62. As in other forms of rotary engines, there are

FIG. 62.



Rotary Engine, R. Dudgeon.

two spur-gears with long engaging teeth, but the steam is admitted at the side *between* the teeth, near the line joining the centres of wheels, and acts to separate the wheels on a line above or below their centres, thereby producing rotary motion. The case is not necessary to secure operation, as it contains only exhaust steam. Two plates on the side of the wheel where the teeth engage are all that are essential, steam being admitted through an opening in one of them. By shifting the plate containing the opening up and down by hand or with a governor, the expansion may be varied to regulate speed, and by moving this opening the other side of the line joining the centres of the wheels, the engine will be reversed. An engine of this kind has been running for six years in New York with superior economy to the ordinary engine formerly employed, and is in as good condi-

tion as when first started. Steam does not blow through, and there is a definite exhaust as each tooth is released.

MARINE ENGINES.

The largest marine engines shown were those exhibited in the Government Building by the United States Navy Department, and consisted of a pair of horizontal engines for the United States steamer *Nipsic*, with cylinders 36 inches in diameter and 36 inches stroke of pistons, and a pair of horizontal compound engines, of the intermediate receiver type, for the United States steamer *Epervier*, with cylinders 34 and 51 inches in diameter and 42 inches stroke of pistons. Boilers for use with the latter were also exhibited. The engines were quite compact, and very well designed and finished.

A small compound marine engine with vertical cylinders was exhibited by the Motala Iron & Steel Company, Motala, Sweden. The Kristenehamn Machine Manufacturing Company, of Kristenehamn, Sweden, also exhibited a small marine engine, and the Köping Mechanical Works, Limited, Köping, Sweden, the cylinders for a 60 horse-power propeller engine. The Swedes construct very simple compound engines, in which the two pistons connect to opposite cranks,—steam being distributed by a single slide-valve arranged between the cylinders.

Messrs. Wm. Cramp & Sons, of Philadelphia, Pennsylvania, exhibited two marine engines, one a vertical engine of moderate size, the other a tastily designed vertical compound engine of the intermediate receiver type, with cylinders 16 and 28 inches in diameter, with 24 inches stroke of pistons. This engine had a steam reversing engine directly connected to the link operating the shaft, the valve of which received a differential motion derived from the hand-lever and the piston-rod, whereby the latter was, by the action of the steam, forced to move coincidently with the former. The device is claimed by *Engineering* (London) to be a modification of Mr. J. McFarlane Gray's steering-gear arrangement. The writer first saw it about the year 1868, in the United States steamer *Algonquin*, the machinery of which was designed by Mr. E. N. Dickerson, and has used a similar device several times since. The Davey differential valve-gear, for pumping engines, is very similar, a cataract engine being used to impart the motion applied in this case through the hand-lever.

Messrs. Neafie & Levy, of Philadelphia, Pennsylvania, had in operation, in Agricultural Hall, one of their vertical engines used for steamers of moderate size.

Models of engines for use on monitors and mortar-boats were exhibited by the Navy Arsenal, Brazil, and a number of complete models of ocean steamers and vessels for war purposes contained complete models of the steam machinery. The models exhibited by Messrs. John Roach & Son, of Chester, Pennsylvania, also of New York, were particularly interesting. They included a beautiful model of an American beam engine complete in every detail, and model engines of a United States iron-clad in actual operation by steam in the model hull.

Mr. F. E. Sickles, of the Providence Steam-Engine Company, Providence, Rhode Island, exhibited original models of some of his early inventions. In his steam steering gear the eccentric operating the valves of the engines is revolved on the shaft by the hand steering-wheel, the engines following with substantially the same velocity. The Sickles trip cut-off, patented in 1842, with improvements, patented 1845, furnished a very simple and efficient means for utilizing the expansion of steam with poppet-valves, such as are used on American beam engines, and at an early date had the effect to draw the attention of engineers and steamship-owners to the importance of the general subject. A dash-pot was provided to arrest the fall just before the valve reached its seat, so that the suppression of steam could be made very promptly; in fact, so as to show a definite angle, instead of a curve, at the point of cut-off on an indicator diagram. In the original plan the valves were tripped by their own motion in lifting, afterwards by their own motion either in lifting or closing, but by a still further improvement they were tripped by an independent movement at any point of the stroke. This arrangement may be seen on many steamers, notably on the *Bristol* and *Providence*, the large steamers of the Fall River line, between New York and Boston.

The Stevens long-toe cut-off was introduced about the same time as the Sickles cut-off. This device lowers the valves at the same speed they are raised, and is much used on account of its simplicity.

The simplest form of trip cut-off yet devised is probably that applied to the beam engines of the Pacific Mail Steamship Company's side-wheel steamers, also to the steamer *Newport*, of the Fall River line, above mentioned, by Mr. Horatio Allen, when president of the Novelty Iron Works, New York. In this arrangement the lifters operating the toes on the valve-stems are each pivoted to the rock-shaft and lifted by the end of a steel bolt in an arm secured to the shaft,—the bolt being pushed back at the proper time to release the lifter by a projection on a curved adjustable tripper. The fall of the

lifter is controlled by a fluid in a chamber. The operating eccentric passes its extreme movement but a little in advance of the crank, so that the cut-off is adjustable for nearly the whole length of the stroke, a separate eccentric being provided for the exhaust-valves as in the Stevens arrangement. The system developed by Mr. Allen, of pivoting both parts of the disengaging apparatus on the same centre so as to insure a direct instead of a rolling contact of the disengaging surfaces, was at a later date applied to Corliss valves on marine engines by Mr. George H. Reynolds.

STEAM-ENGINE INDICATORS.

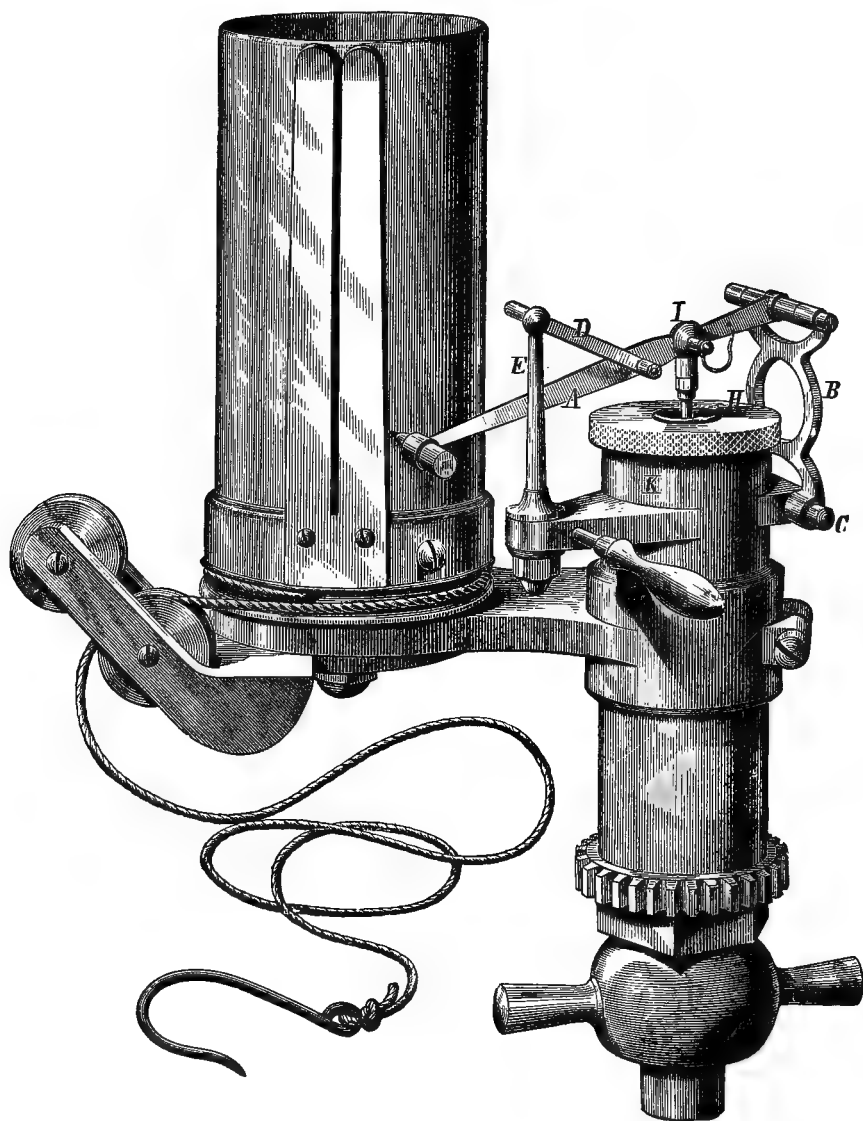
The original form of the steam-engine indicator as invented by Watt, in which the steam-piston had the same movement as the pencil, was found inapplicable for use at high speeds on account of the momentum of the moving parts, which caused large vibrations of the pencil on the paper, and often serious jars with corresponding inaccuracies in the diagrams. In instruments on this plan it was necessary also to take hold of the pencil when in rapid vibration, in order to apply it to the paper. The first indicator adapted for high speeds was that used by Mr. Gooch, of England, for experiments with locomotives, in which the indicator piston was connected with the short arm of a lever and the pencil carried at the end of the long arm. This arrangement permitted the use of a stiffer spring, and reduced the vibrations within moderate limits. The objection was that the diagrams were distorted by the motion of the pencil in an arc of a circle, and particular care was required in measuring them.

In 1862 an important improvement was made by Mr. Charles B. Richards, of Hartford, Connecticut, who applied a simple parallel motion, in place of the single lever of the Gooch instrument, and thereby obtained the ordinary form of diagram with reduced movement of piston. The levers were pivoted to a swinging arm, whereby the pencil could be moved up to the paper without handling vibrating parts. The Richards instrument finally came into general use to the practical exclusion of the old direct forms, and has proved of the highest value to engineers, assisting them in investigations for the purpose of improvement and enabling the performances of all kinds of engines to be satisfactorily compared.

The Thompson indicator, exhibited by the Buckeye Steam-Engine Company, of Salem, Ohio, is a modified form of the parallel motion, or Richards indicator, in which a simpler form of parallel motion is

used than that employed by Mr. Richards, as is clearly illustrated in Fig. 63. The construction still further reduces the momentum of

FIG. 63.



The Thompson Steam-Engine Indicator.

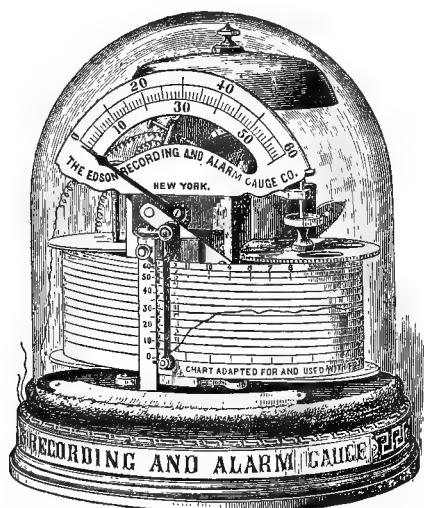
the working parts without apparently introducing any objectionable features.

STEAM-GAUGES.

Steam-gauges were exhibited by the well-known firm of Schäffer & Budenberg, Buckau, near Magdeburg, Germany; by C. W. J. Blancke & Co., Merseburg, Germany; by Messrs. Lion & Guichard, of Paris, France; by E. H. Ashcroft, of Boston, Massachusetts; the Utica Steam-Gauge Company, of Utica, New York; the Buffalo Steam-Gauge Company, of Buffalo, New York; and the Cleveland Steam-Gauge Company, of Cleveland, Ohio.

A gauge for water-works, with 30-inch dial, was shown by Mr. M. B. Edson, of New York, who also exhibited the Edson automatic indicating, recording, and alarm gauge, invented by him, which is illustrated in Fig. 64. In this instrument the variations of pressure

FIG. 64.



Edson's Time and Pressure Recording Gauge.

are recorded on a ribbon of paper, kept in motion by an excellent clock movement, and are indicated also by a hand on a dial in the usual way. The tripping-post of the mechanical alarm (shown at top of the instrument) being insulated, and forming a negative—whereas the instrument is positive—provides a means whereby an electric circuit may be closed whenever the steam (or water) pressure shall exceed any given limit, which is valuable as a precautionary measure, and the records are secured by lock and key. The paper ribbon is printed with graduations and figures, which enable the pressure to be read that obtained at any given time. The instrument can be applied

to record any changes of pressure, and be located in a private office at a considerable distance from the boiler or source of pressure. The gauge is valuable to show the attention paid by watchmen, firemen, and other employees to their duties either day or night, or both, and the records may be made the basis of instructions to secure important economies in management. The instruments are being widely introduced, and their reliability and accuracy were satisfactorily shown during the boiler trials made by a Committee of the group, the report of which is hereto appended.

GOVERNORS.

Time and space will not permit detailed reference to a number of interesting steam-engine governors, foreign and American. There were several new forms in the German, Russian, and Swedish departments, most of which were evidently based upon careful mathematical consideration of the principles involved.

AIR- AND GAS-ENGINES.

The Rider air-engine exhibited by Messrs. Rider, Wooster, & Co., of Walden, New York, was quite interesting. It consisted simply of two connected cylinders, one the cold cylinder or air-pump, the other the power cylinder, with their respective pistons, each connected to a crank above on a rotary shaft. In operation, the air drawn into the cold cylinder is compressed, passed through a regenerator, where it receives its first increment of heat, and is forced into the heater, where, becoming thoroughly heated, the pressure generated acts upon the main piston, driving it upward. When the latter arrives at the top of its stroke the exhaust-valve is opened, allowing the air to escape into the atmosphere, and a fresh charge is taken into the cold cylinder and the operation repeated.

Interesting gas-engines were exhibited by Messrs. Mignon & Rouart, of Paris, France, and by the Gas-Motor Factory, Deutz, Germany. In the Langden & Otto gas-engines, manufactured by the latter company, the piston is detached from the load when the explosion takes place and moves rapidly upward in the cylinder, retarded only by the vacuum formed below it and the atmospheric pressure on the other side. During the return movement of the piston, a pinion operated by a rack on the piston-rod is, by an efficient arrangement, clutched to the main shaft, and the power stored up in forming the vacuum is applied to increase the velocity of the shaft. The governor regulates the frequency of the strokes,—the fly-wheel maintaining the motion during the intervals between them.

STEAM-ENGINE ECONOMY.

In the previous article on the Duty of Pumps, page 20, it is proposed to compare the duties of steam-pumping machinery of all kinds by the calculated amounts of fuel required to furnish the heat in the steam used, on the basis that the boiler is capable of uniformly absorbing 10,000 heat-units per pound of coal consumed. It will be found convenient to compare the performances of all kinds of steam machinery on the same basis. Ten thousand heat-units, per pound of coal with $\frac{1}{8}$ refuse, corresponds to the evaporation of 12.426 pounds of water, on the standard basis, viz., at atmospheric pressure from temperature of 212° , per pound of combustible. Substituting this as the value of E in equation (1), in the article on Boiler Proportions, page 75, it is found that such evaporation should be obtained in a boiler properly proportioned to burn .396 of a pound of combustible, or .475 of a pound of coal, with $\frac{1}{8}$ refuse, per square foot of heating surface per hour. Ten thousand heat-units per pound of coal also corresponds to an evaporation of 8.99 pounds of water at 80 pounds pressure, 9.03 pounds at 60 pounds pressure, or 9.08 pounds at 40 pounds pressure, from a temperature of 100 degrees, in each case. This evaporation is higher than is usually obtained, but has been so much exceeded in the experiments referred to in the article on Boiler Proportions, page 75, that it is not considered too high for a basis of comparison. It represents an ultimate efficiency of only $(10,000 \times 100 \div 14,500 =)$ 69 per cent. of the calorific value of anthracite coal, so that ordinarily more than $(100 - 69 =)$ 31 per cent. of the heat in the fuel is carried to waste up the chimney. A still greater loss is, however, experienced in utilizing the steam for the purpose of work in the engine. The mechanical equivalent of one heat-unit is 772 foot-pounds, which, on the basis referred to above and at page 21, corresponds to a duty of 772 millions of foot-pounds per 100 pounds of coal. The most economical steam-engines, for instance, pumping-engines of approved types, utilize in the steam-cylinder only about 130 millions, on the same basis, equivalent to an ultimate efficiency of $(130 \times 100 \div 772 =)$ 16.84 per cent. of the heat in the steam, and but $(16.84 \times .69 =)$ 11.62 per cent. of the calorific value of the fuel. The principal reason for this is that the exhaust steam necessarily carries to waste the heat required to maintain it in a vaporous state at the tension due to the back pressure. This under the most favorable circumstances forms the larger proportion of the total heat of the steam and reduces the opportunities for securing economy within

small limits compared with the theoretical limit, although the differences between the performances of different engines are great when compared one with another.*

To secure economy of fuel within the limits indicated, it is usual to employ the free expansion of steam of high pressure. In practice, however, the full benefit of expansion cannot be obtained, on account of internal condensation, it being found that even in the best engines a much larger quantity of steam is used than is due to calculations based on the terminal pressure. Various reasons have been assigned for this, but it is now generally conceded to be due to the differences of temperature in the cylinder and the consequent transfers of heat to and from the metal walls. Some writers having expressed doubts that this was sufficient to account for the great condensation observed, the writer in the year 1866 made some experiments on the subject. Two small cylinders or chambers, without pistons, were constructed—one of glass, the other of iron—of exactly equal capacities, and carefully felted, each of which could in turn be connected with a valve operated regularly by an engine to admit steam from the boiler to the experimental cylinder, and permit it to exhaust to a condensing coil. The exhaust opened slowly at first and rapidly afterwards, so that the pressure in the cylinder would approximate that in an ordinary steam-cylinder. The result was that the condensed steam from the iron cylinder was in nearly every case fully double that from the glass cylinder.† The apparatus was sufficiently compact to form part of that of an institution of learning, and showed that the cylinder is

* In view of discussions in progress at the date of writing on the proper details of a theoretically perfect steam-engine, it is proper to mention that in the year 1868 the writer designed and partially constructed a non-exhausting experimental engine in which the steam, after expansion in the cylinder, was to be circulated through another vessel, to withdraw the water due to the performance of work; the dry steam was then to be returned to the cylinder and compressed, which it was expected would require less power than the expansion would furnish, and sufficient steam only be received from the boiler to supply that condensed for work. A demonstration of the correctness of the principle only was intended, the power expected being so small that the experimental engine was to be connected to another to keep it in motion. Before the apparatus was completed the funds were diverted to objects of greater immediate necessity, and the subject is mentioned only as indicating the general principle upon which a theoretically perfect steam-engine may be constructed. See description of the apparatus in article on the "Theoretical Steam-Engine," *Scientific American Supplement*, Aug. 18, 1877. See also Prof. Thurston's calculations on a similar subject in *Journal of the Franklin Institute*, Oct., Nov., and Dec., 1877.

† See *American Artisan*, March 8, 1871. The experiments mentioned in the text were followed up by others with engines of moderate size provided with cylinders lined with non-conducting materials, which gave economical results, but were not adapted for practical use on account of the brittleness of the vitreous materials used for linings.

still a condenser the same as before the days of Watt, and that his invention of a separate condenser only reduced the extent of the loss. Tyndall points out in *Heat as a Mode of Motion* that the small amount of moisture ordinarily contained in the atmosphere has 70 times the absorptive effect, in relation to latent heat, of dry air. Steam chilled by the performance of work, or by reheating the metal walls previously cooled during the exhaust stroke, contains minute suspended particles of water with a great capacity for heat, which almost instantaneously absorb that necessary for their re-evaporation from the surrounding walls, and this action is at a maximum when the exhaust takes place and all the heat absorbed is carried to waste. The live steam supplied to the cylinder must evidently reheat the surfaces as rapidly as the pressure rises to produce the dynamical effect, and a portion thereby become condensed, so that a much larger quantity of steam is required than that simply due to the volume at the point of suppression.

The want of full knowledge on this subject has caused great differences of opinion and consequent errors in design. One class of steam engineers considered only the calculated results due to expansion, based on theory as it was called, or the law of Mariotte simply, without allowing for the thermal conditions under which expansion must take place, and constructed engines so *large* as to defeat the object in view. Another more limited class considered the subject of cylinder condensation in too serious a light, and from the results of a few experiments at moderate pressures concluded that all the beneficial results could be obtained with a very moderate expansion, and on that basis constructed engines too *small* for economy. Evidently a correct theoretical discussion of the subject should include the thermal conditions under which the steam must do its work, and which will vary for every difference in steam pressure, in the quality of the steam, the ratio of expansion, the size or proportions of the cylinder, the speed of the piston, etc.

Means for securing economy in steam-engines may be divided into two classes, viz., those of a mechanical nature and those which influence the thermal conditions. As to the first, the necessity of securing tight pistons and valves, ample area of cylinder passages, reduced clearances, etc., are well understood, also the incidental advantages due to a certain degree of compression. Those of the second class act to reduce the cylinder condensation, and include high speeds of revolution, steam superheating, steam-jacketing, and the compounding of engines. High speed of revolution (which does not necessarily imply high piston speed, as generally understood) secures economy, by re-

ducing the time in which the transfers of heat to and from the steam and inclosing walls must take place.*

Superheating the steam has experimentally proved effective for moderate rates of expansion, in which the original temperature required to maintain the gaseous condition of the steam to the point of release was not too high to prevent proper lubrication. Mr. Geo. P. Dixwell, of Boston, Massachusetts, has applied a thermometer to a steam-cylinder, by inspection of which it is possible to regulate the temperature so as to prevent injury to the metal surfaces. The great difficulty is, however, to secure a permanent and reliable superheating apparatus. Steam-jacketing has to a limited extent advantages of the same kind as superheating, and involves no serious difficulties in management. The jackets are most effective on long cylinders of small diameter. In experiments with United States revenue steamers, hereinafter mentioned, the economy of a steam-jacket on a comparatively short cylinder was found to be 11 to 12 per cent.

Compound engines, in addition to advantages of a mechanical nature, in better distributing the strains and rendering more uniform the rotative efforts, serve also to reduce cylinder condensation by the distribution of the differences of temperature between two cylinders. The radiation to and from the steam and its inclosing walls increases more rapidly than the difference in temperature, so that the sum of the losses, when the difference of temperature is divided between two cylinders, is less than when it all occurs in a single cylinder. Moreover, the heat imparted to the exhaust steam by the metal of the first cylinder is available for work in the second, and the low-pressure piston acts as a screen between the high temperature in the small cylinder and the low temperature in the condenser.

It is still strenuously denied by many that greater economy can be secured with a compound engine than with a long-stroke single engine using the same steam pressure. There are coasting steamers of similar size running regularly in the United States using both types of engine, with, it is claimed, substantially the same results; but the boilers for the single engines are evidently the more economical, making an accurate comparison impossible. Strictly comparative experiments have, however, been made by Chief Engineer C. H. Loring, U.S.N., and the writer with engines of different kinds in the

* The value of this saving was determined by the writer for the Novelty Iron-Works, Mr. Horatio Allen, President, in the year 1868, and embodied in a series of tables showing the relative power and economy of different sizes of steam-engines, which tables were afterwards published by Prof. W. P. Trowbridge, the former Vice-President of the company.

steamers of the United States Revenue Marine, and by the writer with some of those of the United States Coast Survey.*

The revenue steamers were of the same size and the boilers very nearly identical. In one steamer was a compound engine with steam-jacketed cylinders; in another, a long-stroke, high-pressure condensing engine (cylinder not jacketed); in another, an ordinary low-pressure engine (cylinder not jacketed); and in still another, a high-pressure condensing engine with a jacketed cylinder. The compound engine showed a saving of 12 to 16 per cent. compared with the best performance of either single engine when operated at the same steam pressure. It is believed that substantially the same differences will be found in all cases when equally good engines of both types are compared. The performance of a short-stroke compound engine may be equaled or even excelled by that of a long-stroke single engine, on account simply of the difference in clearance spaces and the superior efficiency of the steam-jacket in the latter case, but by making the compound cylinders in the same form they should still show an advantage. In practice, the economy of marine compound engines is greater than above mentioned, for the reason that the high steam pressure is better maintained with them by the engineers than when single cylinders are used with high rates of expansion, causing difficulties in management.

The following table shows the performance of one of the Leavitt compound beam pumping-engines, at Lawrence, Massachusetts, described in article on Pumping-Engines; also that of the engines of the *Rush*, one of the revenue steamers previously referred to in this article :

APPROXIMATE STEAM PRESSURE.	RATIO OF EXPANSION.	DIAMETER OF CYLINDER.		STROKES OF PISTONS.	REVOLUTIONS PER MINUTE.	PISTON SPEED.	MEAN PRESSURE REFERRED TO LARGE CYLINDER.	INDICATED HORSE-POWER.	WATER PER INDICATED HORSE-POWER PER HOUR.
		Inches.	Inches.	Inches.		Feet per Minute.	Pounds.		Pounds.
90	13.5	18	38	96	16.27	260.3	22.15	196.4	14.02
70	6.22	24	38	27	70.84	318.8	24.48	266.6	18.38

*See article by the writer on "Compound and Non-Compound Engines," *Transactions American Society of Civil Engineers*, vol. iii. p. 68, 1875; *Journal of the Franklin Institute*, Feb. and March, 1875; *Engineering* (London), Jan., Feb., and March, 1875; *Proceedings of Institution of Civil Engineers* (British), vol. xl. p. 292, and vol. xli. p. 296; also report of trial of United States revenue steamer Gallatin, *Journal of the Franklin Institute*, Feb., 1876, and vol. xxi., *Engineering*, 1876.

The comparison is very interesting. In both engines the larger cylinders are of the same diameter, but the difference in the duty for which the engines were designed required great differences in other proportions and in all the details of construction. In the pumping-engine for use on land there were no restrictions as to weight and space, so a comparatively long stroke could be employed and the connections made through a beam. The marine engine had, however, to be located in a small vessel, and was therefore directly connected and proportioned accordingly. Yet the long-stroke engine was run with so much expansion and at so slow a speed as to develop less power than the smaller one, and the latter was less economical, on account of the lower steam pressure and rate of expansion and the relatively greater proportion of waste room in the cylinder, incident to the necessary use of ordinary slide-valves. The engine of the *Rush* was, however, more economical than the ordinary stationary compound engines used for manufacturing purposes, as the latter, according to published reports in the engineering journals, require the evaporation of not less than 20 pounds of water for each indicated horse-power. The Lawrence engine contains all well-known means for securing maximum economy of steam, and it is probable that few if any engines are working with greater economy in respect to the indicated power. The performance is, however, much below that given by calculation when all the conditions are taken into consideration, other than the slight distortion of the theoretical indicator diagram found in practice and the important loss due to cylinder condensation.

In an engine using a total pressure of $(90 + 14.7 =) 104.7$ pounds, expanded 13.5 times in a cylinder, with clearances, etc., equal to .02 of the displacement, the calculated cost of one horse-power per hour, or 1,980,000 foot pounds, should be only 8.12 pounds of water evaporated from the initial pressure, on the basis that the curve of expansion is hyperbolic, and that the consumption of steam equals the volume at the initial pressure required to fill the cylinder to the point of suppression, plus that condensed for the total work. With a pressure of 100 pounds above the atmosphere, and an expansion of 20 times, there should be required on same basis the evaporation of only 6.00 pounds of water per indicated horse-power per hour. It is probable that the practical results obtained with the latter pressure and expansion would be little or no better than those from the Lawrence engine, on account of the greater cylinder condensation due to the increased expansion.

The above-calculated performances, and the practical results ob-

tained with engines and other steam machinery of various kinds, is shown in the accompanying table, in connection with the relative efficiencies obtained by considering the heat-units in the steam and the calorific value of the fuel:

NUMBER OF LINE FOR REFERENCE.	1	2	3	4	5	6	7	8
	DESCRIPTION.	STEAM PRESSURE.	RATIO OF EXPANSION.	WATER EVAPORATED PER INDICATED HORSE-POWER PER HOUR.	Comparative Results on Basis that 10,000 Heat-Units are imparted to Water per Pound of Coal. See pages 21 and 115. (Calculations based on a Temperature of Feed of 100°.			
					DUTY IN MILLIONS OF FOOT-POUNDS, PER INDICATOR, PER 100 POUNDS OF COAL. PAGES 21 AND 115.	RELATIVE EFFICIENCY, BASED ON THE PROPORTION UTILIZED OF THE TOTAL HEAT OF THE STEAM.	RELATIVE EFFICIENCY, BASED ON THE PROPORTION UTILIZED OF THE CALORIFIC VALUE OF ANTHRACITE COAL.	NET EFFECTIVE DUTY FOR LIFTING WATER, IN MILLIONS OF FOOT-POUNDS, PER 100 POUNDS OF COAL.
1	Calculated performance.							
2	Maximum				772.0	1.00	1.00	
3	Calculated performance (see page 120).....	100	20	6.005	295.2	.382	.264	
4	Calculated performance.....	90	13.5	8.122	218.6	.283	.195	
5	Lawrence compound beam pumping-engines.....	89.4	13.7	14.019	126.7	.164	.113	
6	U. S. Revenue steamer Rush,* compound engine.....	69.2	6.22	18.384	97.03	.126	.087	
7	U. S. Revenue steamer Gallatin,* vertical cylinder with steam-jacket.....	67.2	4.19	21.48	83.08	.108	0.74	
8	U. S. Revenue steamer Dexter,* vertical cylinder without steam-jacket.....	67.1	3.49	23.905	74.66	.097	.067	
9	U. S. Revenue steamer Dallas,* vertical cylinder without steam-jacket.....	32.0	3.13	26.945	66.91	.087	.060	
10	U. S. steamer Mackinaw,† inclined cylinder without jacket	49.0	2.2	30.306	59.16	.077	.053	
11	U. S. steamer Mackinaw, steam superheated.....	52.0	3.2	22.725	78.83	.102	.070	
12	Non-condensing engine, with governor cut off,‡ (st. jacket).	81.7	5 0	25.482	69.81	.090	.062	
	Non-condensing engines, regulated by throttle.....				30 to 45	.04 to .06	.03 to .04	
13	Pumping-engines.....							30 to 110
14	Steam-pumps. Large size proportioned for the work to be done.....							15 to 30
15	Steam-pumps. Small sizes for ordinary uses. See page 22.....							8 to 15
16	Vacuum-pumps. See page 21.....							3 to 10
17	Injectors when used for lifting water not required to be heated. See page 96.....							2 to 5

* See references in foot-note, page 119.

† See vol. II., Isherwood's *Experimental Researches in Steam Engineering*, pp. 77-116.

‡ *American Institute Reports*, 1869-70, 1870-71.

MOTORS AND TRANSMITTERS, HYDRAULIC APPARATUS, ETC.

BY W. H. BARLOW.

(Extracts from the Report to the British Commission.)

The classes which came under my more particular observation were Nos. 551, 553, 560, 563, and 567. Class 551 is described in the Official Catalogue as containing "Water-wheels, Water-engines, Hydraulic rams, Windmills, etc." There were not, however, any windmills in this class, for, although the study of windmills has received much attention in America, and many were exhibited of very clever construction, yet they were all applied to agricultural drainage, and as such were put under the class of "Agricultural Appliances." By far the largest proportion of motors in Class 551 were turbines. Of these, about fifty were contributed by the United States and six or eight by Canada. Drawings of turbines of excellent design were exhibited by Sweden. In fact, the only water "Motors" having for their object the production of power on a large scale were turbines. There were a few other water-engines for generating power, but only for use by hydrants or otherwise, where small amounts of power are required, as for sewing-machines, turning-lathes, etc. From the extensive display of turbines and the general absence of other large water-motors, it would appear that in the United States and Canada the practical advantages of turbines have caused them to supersede water-wheels and other water-motors.

The form of turbine most numerous exhibited was that patented by Mr. Leffel, of which two were contributed by the firm of the inventor, Messrs. James Leffel & Co., Springfield, Ohio, and several others by different manufacturers working under his patent. Although not theoretically perfect under all conditions, the very large use made of Mr. Leffel's invention is evidence of its practical utility.

Various forms of turbine were exhibited, and generally the workmanship was of high quality, with much attention bestowed on the arrangement of working parts. There were few departures from the generally-known forms of these engines; that furnished by Messrs. Harris & Co., St. John, New Brunswick, being an exception, and I believe untried as regards its advantages.

There were, however, some features of novelty, as, for example, Bollinger's patent (O. J. Bollinger, York, Pennsylvania), in which the

turbine is so arranged that in the event of accident the gates can be set free and close by the pressure of the water. The arrangement made for this object is very simple and effective.

Messrs. E. T. Cope & Sons, West Chester, Pennsylvania, furnish a turbine supplied with the means of shutting off the gates in succession. Mr. Silas Walton's turbine (Moorestown, New Jersey) is very skillfully designed for effecting the coincident regulation of the guides and wheel-buckets.

There were a few good contrivances for the application of small amounts of hydraulic power from hydrants, among which some of the best examples were those of Mr. Albert G. Buzby, Philadelphia, Pennsylvania. These are incased water-wheels operated by jets of water, an arrangement which is very simple, effective, and compact.

The hydraulic ram sentinels, furnished by Mr. W. W. Grier, Hulton, Pennsylvania, are very useful in cases where a hydraulic ram is worked by a stream too small to keep it continuously working. The ram-sentinel has the property of putting the ram into action automatically whenever the water accumulates in sufficient quantity to work it.

An ingenious arrangement was exhibited by the Hartford Pump Company, in which a windmill is made to work an air-pump of such construction as to cause a continuous flow of water from a brook or other supply. It is applicable to those places where wind-power can be obtained on high ground, near to a brook or well at a low level.

In concluding Class 551, mention should be made of the excellent castings of penstocks and gearing and belt-drums by Messrs. Poole & Hunt, Baltimore, Maryland, and to the 10-foot belt-drums cast by Messrs. R. D. Wood & Co., of Philadelphia.

CLASS 553.—APPARATUS FOR THE TRANSMISSION OF POWER, SHAFTING, BELTING, CABLES, ETC.

In this class leather-belting occupies a prominent position. The extensive use made of belting as a transmitter in the United States and also in Belgium has led to a high degree of excellence in the production of belting in those countries.

The finest examples made in the United States are of leather, some of them 28 inches in width and of excellent quality.

Belgium exhibited, besides leather, hair machine belting, a manufacture which is said to be cheaper in cost and greater in strength, and not injuriously affected by water.

In degree of importance, however, and from the extensive and varied uses to which it is applied, wire rope claims a higher place.

Messrs. John A. Roebling's Sons & Co. were the only exhibitors of wire rope, but their contribution to the Exhibition was of the most striking character as regards its extent, the perfection of workmanship, and the magnitude of some of the samples. Among the cables shown by Messrs. John A. Roebling's Sons & Co., Trenton, New Jersey, were those used for the Niagara Railway Bridge (820 feet span), the Cincinnati and Covington Bridge (1054 feet span), and that designed for the bridge between New York and Brooklyn (1595½ feet span). This latter cable is 15½ inches diameter, and contains 6000 strands of No. 7 cast-steel wire, galvanized.

Another important class of transmitters is shafting, of which excellent examples were furnished by Messrs. Poole & Hunt, Baltimore, but the most striking manufacture of shafting was that of Messrs. Jones & Laughlin, Pittsburgh, Pennsylvania, made by the process of cold rolling. These shafts are first passed through the rolls hot; the scale and oxide are then removed by immersion in acid, after which they are subjected to cold rolling in cast-steel rollers. This process, besides giving a bright finished surface, compresses and condenses the outer portions of the metal to an extent which adds materially to its strength in resisting tension, compression, and torsion. More than 1100 feet of this shafting were in daily use in the Machinery Building, besides about 1000 feet in the Agricultural Hall.

Of the methods of coupling round shafts together, that of Mr. John Charlton, Philadelphia, Pennsylvania, is well deserving of notice. Simple and effective in construction, it is complete in its action, whether the shafts connected by it are of the same or different diameters.

Ewart's detachable driving-chains, Ewart Manufacturing Company, New York, form an efficient means of transmitting power. They are formed of cast malleable iron links, any of which can be detached or others added so as to shorten or lengthen the chain. The links work on to cogs on the driving-wheels, and the working is smooth and even.

Among the apparatus connected with shafting, the self-oiling bearings of M. Dufrene, of France, were exhibited. The oil is placed in a receptacle formed in the lower part of the bearing, and supplied to the moving part by capillary attraction through cotton-wick. By this means the oil is supplied quite clean, all foreign matter being left in the receptacle below. The working of these bearings is said to be very satisfactory.

CLASS 563.—HYDRAULIC JACKS, PRESSES, ELEVATORS, LIFTS,
METERS, AND CRANES.

The most numerous objects in this class were elevators. In those applied to passenger purposes, one main object of attention is directed to the provisions for safety in the event of the supporting rope or chain breaking.

Messrs. Otis, Brothers, & Co., New York, exhibited a well-known form of elevator with safety rack. Messrs. Andrews secure safety by the friction of wedges against wooden uprights,—an arrangement which is said to work well.

Mr. Joseph Goldmark, New York, exhibited a novel method of attaining the same object. The lifting is effected by a strong, flat-linked endless chain, working in a groove, and so arranged that the chain can only move in the direction of the length. Thus, if the suspending part of the chain breaks, the lower part below the carriage, being unable to move laterally in its groove, becomes a rigid support to the carriage.

It is to be observed that in the elevators used in some of the principal hotels safety is secured by employing several supporting ropes operating at the same time, any one of which is capable of bearing the entire weight. Some of these elevators not only worked admirably, but were rendered attractive by the elegance of their internal fittings, and it is much to be regretted that they were not exhibited at the Centennial.

The largest and most imposing-looking machine in Class 563 was the steam hydraulic cotton-press of Mr. John F. Taylor, of Charleston, South Carolina. It is constructed with two hydraulic cylinders 22 inches diameter and 4 feet 10 inches stroke, and worked by two steam-cylinders on the compound principle 56 inches diameter and 8 feet stroke. This powerful machine is very efficient and expeditious in its operation and economical in consumption of fuel. It is stated to be capable of pressing 930 bales in 10 hours.

An extremely ingenious compound hydraulic press was exhibited by Messrs. Bolen, Crane, & Co., of Newark, New Jersey. It is a machine of great power, obtained by the accumulated action of several divisions of the press acting on one plunger, so that with a comparatively low pressure of water a very large power of pressing can be given. The construction is very simple, and the mode of obtaining the action is new, but the range of distance through which the plunger can move is limited to less than that of ordinary hydraulic presses.

M. Morane, Jr., of Paris, exhibited a press of excellent construction

for extracting oil from stearine. This machine, which is used for candle manufacture, is most carefully made, well adapted to its purpose, and of excellent workmanship.

There were several clever contrivances invented by Mr. T. A. Weston, and exhibited by the Yale Lock Manufacturing Company, Stamford, Connecticut. They involve novel applications of mechanical action,—first, in the accumulated action of frictional surfaces; second, in the means of applying friction-clutches through the driving-shaft; and, third, an arrangement whereby the power required to lift a weight can be varied while the weight is suspended and in motion.

The gunpowder pile-driving machine, exhibited by the Gunpowder Pile-Driver Company, of Philadelphia, was a well-made example of this ingenious and effective class of engine.

M. J. Chrétien, of Paris, furnished a model of a form of steam-crane extensively used in France. The steam-cylinder is in the jib, and operates by lengthening and shortening the jib, and so obtaining the lifting power.

Appley Brothers, of London, exhibited steam-cranes of excellent and substantial workmanship.

There were many other articles in this class, such as hand-hoists, hod-hoists, double screw-jacks, quadruple screw-presses, etc., but they did not contain features of construction calling for special remark.

CLASS 560.—PUMPS AND APPARATUS FOR LIFTING AND MOVING FLUIDS.

This class contained a large number of articles, and a great variety of constructions. The most prominent, both in number of exhibits and in power as machines, were rotary pumps and direct-acting steam-pumps. Rotary-pumps were exhibited by the United States, Great Britain, Canada, France, and Belgium. One of these machines in actual operation in the building, exhibited by Messrs. Heald, Sisco, & Co., Baldwinsville, New York, delivered a full bore stream of 12 inches diameter. John and Henry Gwynne, Hammersmith Iron-Works, London, exhibited a beautiful model of their rotary pumps which have been erected at Codigoro, near Ferrara, Italy; they are of immense size, estimated to be capable of raising 2000 tons of water per minute from 10 to 12 feet high. M. Léon Moreau, of Brussels, exhibited a model pump in which the principle of close contact is practically maintained throughout the rotation. This is an excellent machine for perfectly clean water, but apparently liable to derangement by any gritty particles.

With one exception all the direct-acting steam-pumps which came under my observation were produced by makers in the United States. They were generally of very good workmanship, with careful consideration given to the details, especially as to the steam-cushions for the main pistons, and the facilities for obtaining access to the valves and replacing them when required. In several of these pumps the valves themselves were moved by steam, without the intervention of tappets, of which construction those by Messrs. Edward Dart & Co., New York, and Mr. Jonathan Pickering, Globe Works, Stockton-on-Tees, were examples. In the pump exhibited by the Norwalk Iron-Works Company, South Norwalk, Connecticut, the action of one valve governs the whole movement. The Niagara Works, Brooklyn, New York, in addition to their direct-action pumps, exhibited a good crank pumping-engine, with a simple screw-coupling to connect it with its pump, and so arranged that when disconnected from the pump the engine is available for any other work. Crane Bros.' Manufacturing Company, Chicago, Illinois, exhibited large pumps, with 18-inch diameter of barrel. Knowles' Steam-Pump Works, New York, produced a fine display of pumps of large size, blowing-engine, heavy lift mine-pumps, etc.

There were six or more exhibits of pulsometer-pumps, all by American makers. The attractive feature of these steam-pumps consists in the simplicity of construction, the absence of pistons, and the very small amount of working parts. Pulsometer steam-pumps are cheap in construction and in repairs, but not economical in the steam required to work them, in consequence of loss by condensation. Nevertheless there are many circumstances and conditions under which the employment of pulsometer-pumps would be of great utility.

The vacuum-engines, of which there were several, are for the most part intended to be worked, or are capable of being worked, by the exhaust steam of engines employed for other purposes. Under these conditions the work obtained from them is so much waste power utilized. In both pulsometer and vacuum pumping-engines the tendency to loss by condensation is diminished by lining the vessels with wood or non-conducting paint. These pumps do not choke by sand or other small particles of solid matter. The vacuum-pump of Messrs. Nye, Gourlay, & Co., Chicago, Illinois, is favorably reported upon by the engineers of the United States navy.

The pump exhibited by the New York Hydraulic Drainage Company differs from the others in having three cylinders or steam-vessels instead of two, and the valves, instead of being automatic, are worked by a small water-wheel, operated by the water delivered from

the pump. Two forms of propeller-pumps were exhibited in the United States department. One by the Hydrostatic and Hydraulic Company consists of a series of propellers on one shaft, contained in a straight vertical cylinder. The other has two shafts working two series of propellers, the propellers on one shaft being opposite the spaces between the propellers in the other. In this pump the cylinder is bent from side to side to suit the position of the propellers, and the shafts revolve in opposite directions. In the first-named pump the upward flow has the advantage of a straight cylinder, but the action of the propellers imparts a rotary movement to the water. In the other the tendency to a rotary movement in the water is prevented by causing the two shafts to revolve in opposite directions, but the upward flow of water has to pass through the several bends of the cylinder. The relative merits of these two pumps can only be ascertained by actual test; but one remark is common to both, namely, that with sufficient power water can be raised to very great heights. The straight cylinder-pump is stated to have raised water 278 feet high.

Messrs. Sluthour & Mintzer, Philadelphia, Pennsylvania, exhibited an oscillating bilge-pump of very simple construction, and Messrs. Wilson, Clarke, & Co., Yarmouth, Nova Scotia, had a good sample of pump for the same purpose. There were several examples of excavator-pumps, some adapted to sewage, and provided with arrangements to render the operation odorless. Matthewman & Johnson, New Haven, Connecticut, and Mr. Isaac Hyneman, Philadelphia, Pennsylvania, and the Odorless Excavating Company, exhibited good examples. These pumps are capable of moving fluids charged with a large amount of solid matter, such as small stones, broken bricks, etc.

Hand-pumps remarkable for simplicity and cheapness were exhibited by the United States and Canada. The double-acting two-valve pump of Mr. W. H. Harrison, Philadelphia, Pennsylvania, is an original idea, but its practical advantages require testing. Fine examples of fan-blowers were exhibited by Mr. B. F. Sturtevant, Boston, Massachusetts. In one of them the fan was 67 inches diameter. The workmanship was excellent, and the details carefully considered.

There were two examples of hydraulic rams. One by Messrs. A. Gawthrop & Son, Wilmington, Delaware, was a double ram, so arranged as to enable a supply of good water to be raised by a stream of any other water which may be available in sufficient quantity. The other hydraulic ram, together with some pumps, were exhibited by M. T. C. da Costa, of Brazil, and were interesting as exhibiting a new branch of industry in that country. In this class was also a tank for the

storing of inflammable oil,—a very ingenious construction invented by Mr. Stephen Webster, St. Catherine's, Ontario. It is so arranged that the oil is always surrounded by water. The difference in the specific gravity of oil and water enables the oil to be drawn from the upper surface of the water, while it can be filled again by a tube, which, by increasing the column, causes the oil to displace the water. The tank can be sunk in the ground out of danger both of fire and lightning. Two water-extractors of good construction were exhibited by the American makers, Mr. W. P. Uhlinger and Mr. H. Chapman, both of Philadelphia, Pennsylvania.

Besides the numerous forms of pumps and hydraulic apparatus mentioned there were fine displays of pumps adapted to various purposes, hydraulic rams, and many other hydraulic engines. Among the imposing displays of this character may be mentioned those of Messrs. Rumsey & Co. (limited), Gould's Manufacturing Company, both of Seneca Falls, New York, and Messrs. W. & B. Douglass, Middletown, Connecticut.

The only other objects which came under the special attention of Committee B were the diving-dresses (Class 567). There were but two exhibits,—one from the United States, the other from Great Britain. The exhibitors were Mr. J. W. Bolles, Baltimore, Maryland, and Messrs. Siebe & Gorman, of London. Both were well made and well fitted in their appliances.

Speaking not only of those classes which fell more immediately under the observation of the Judges in Committee B, but also from general observation of other classes in the group, one cannot fail to notice the great fertility of invention displayed in America, and the excellent workmanship obtained by the joint effect of their tools, machinery, and skilled workmen. Compared with English machinery, that of America appears somewhat lighter, and, although not deficient in strength, is perhaps not so well adapted to those cases where great steadiness of action and freedom from vibration is required; but ingenuity of device and fertility of mechanical resource is everywhere observable. The aim at improvement takes two different directions,—one being that of obtaining simplicity and cheapness of construction, putting the cost of working as of secondary importance; the other being the endeavor to obtain high perfection in the details and great economy of working, treating the cost of construction as of less importance. The one in fact being aimed at cases where engines and machinery are employed for temporary purposes, the other directed to those cases where continuous working is the object.

The production of a given result by the cumulative effect of a repetition of similar mechanical actions is a peculiarity frequently observable: as, for example, in Bolen, Crane, & Co.'s compound hydraulic press, where the pressure is obtained by the accumulated action of a series of similar disks; in Weston's brake, in which great friction is obtained in like manner; the propeller-pumps, which attain their result by the cumulative action of a series of similar propellers; and the injector of Messrs. Nathan & Dreyfus, New York, which is in effect the cumulative action of several injectors.

As a whole the Machinery Hall gave me a high opinion of the mechanical skill of the Americans. There is great inventive power, and a ready and fearless adaptation of the means to the end sought. In considering what is displayed in the numerous and varied contrivances, it has to be borne in mind that many of them come from distant parts of the country, and have to be contrived out of such materials and with such means as may be at hand. But in the machines and apparatus from the larger establishments and more favorable localities, the workmanship is admirable, and every working part down to the smallest detail bears evidence of thought and study.

TESTS OF STEAM-BOILERS.

PROF. FRANCIS A. WALKER, *Chief of Bureau of Awards :*

SIR,—I submit herewith the report of Messrs. Emery, Porter, and Belknap, members of the Judges of Group XX., who, shortly before the close of the action of the Judges, were appointed a Committee to determine by suitable trials the performance of each of the boilers in use at the Exhibition.

It will be seen that care has been taken to include every essential particular, and that the manner of conducting the trials and recording the facts is of the most reliable character.

Respectfully submitted,

HORATIO ALLEN,

Chairman Group XX.

TESTS OF STEAM-BOILERS.

HORATIO ALLEN, ESQ.,

Chairman of Group XX., International Exhibition, 1876.

SIR,—We have the honor to transmit the following report of the trials of the principal steam-boilers used at the International Exhibition in Philadelphia.

§ 1. These trials were, at the request of the administration, conducted under the general direction of a committee of Judges of Group XX. The undersigned, who were selected by the group as the committee for that purpose, prepared instructions, which were issued by the administration to the exhibitors and others interested, in the latter part of August, 1876, in an official printed circular, a copy of which is appended as Exhibit B.

§ 2. The experiments commenced on September 16, 1876, and were terminated November 11, 1876, the day after the close of the Exhibition. The records of the experiments, and cuts of the boilers, appear in the Report of the Bureau of Machinery, appended to the Director-General's Report, and are also presented herewith. These, in connection with the original records and drawings for comparison, and the statement of the assistant in charge, form the basis upon which this report is founded.

The printed logs* of the experiments have been carefully compared with the originals, and are presented as Exhibit C.

§ 3. The primary object of the trials was to enable the exhibitors to ascertain their standing in relation to one another, an opportunity for which, it is understood, had been promised by the Bureau of Machinery. The Judges, in accepting the invitation to take charge of the matter, proposed what in the end should prove a more important object, viz.: to present to engineers and others interested a trustworthy record of experiments made with boilers widely different in type and proportions, from which the general knowledge of the profession in regard to the effect of known modifications could be enlarged, improvements made in rules referring to the subject, and

* "Logs,"—a nautical term, signifying in this connection *records*.

manufacturers be enabled to adapt their proportions to the specific object to be accomplished.

The tests were made while the Exhibition was in progress, and the time was limited; so simple methods were necessarily adopted, but on as comprehensive a plan as seemed possible under the particular circumstances.

§ 4. Fourteen boilers were tested in the order named,—viz.: the Weigand, the Harrison, the Firmenich, the Rogers & Black, the Andrews, the Root, the Kelly, the Exeter, the Lowe, the Babcock & Wilcox, the Smith, the Galloway, the Anderson, and the Pierce boilers.

A brief description of these boilers will be found in § 36 to § 49, inclusive. Illustrations of them are presented as Exhibit A.

§ 5. As provided in the instructions (Exhibit B), two tests, each of eight hours' duration, were made of each boiler; the first with full natural draft and clean fires, to determine the potential evaporation; the second with fires regulated to burn about three-fourths as much coal as before, or, in other words, to approximate average working conditions, with a view of ascertaining the economical evaporation.

Calorimetric observations of the quality of the steam were taken at stated intervals during all the tests, and have been considered in computing the results.

§ 6. The steam generated by the boiler undergoing test was utilized by being blown directly into the main steam-pipe connected with other boilers, and supplying the engines in the various buildings. The pressure in the boiler under trial was maintained at 70 pounds per square inch by regulating the stop-valve, an employee being detailed for the purpose, for whose observation a special steam-gauge was provided.

§ 7. Before beginning an experiment, steam was raised to 70 pounds, when the stop-valve was closed, fires hauled, and ash-pits cleaned. As soon as new fires could be established with weighed wood and coal, the water-level was noted (with fire-doors closed and fires burning), after which the stop-valve was opened; the time of opening the valve being recorded as the time of starting the test. After steaming for eight hours the stop-valve was closed and the water-level again noted (with fire-doors closed); the fires were then hauled and extinguished, and the ash-pits cleaned out.

§ 8. All the coal and kindling-wood, estimated at its equivalent in coal, consumed for starting and maintaining new fires were charged to the boiler, and all the water pumped into the boiler to maintain the level at the same height was credited to the boiler as evapor-

ated, subject to corrections indicated by the calorimeter, as explained below.

§ 9. In the two tests of the Kelly boiler, the economy trial of the Exeter, and the economy trial of the Babcock & Wilcox boilers, the level at stopping was higher than at starting; and for those tests the amounts of water corresponding to the differences in level have been deducted from the amounts pumped into those boilers. In all other cases, however, the level at stopping was the same as at starting, or when lower a few strokes of the pump would bring it up to the required point, the water thus pumped being of course credited to the boiler as having been evaporated.

§ 10. In all cases precautions were taken to trace all connections to the boiler on trial, to see that they were tight; and all blow-off pipes were disconnected, so as to detect any leak that might occur through the blow-off valves. In two or three instances slight leaks occurred, but all the water was collected and deducted from the amount fed into the boiler.

§ 11. Before starting, the approximate amount of coal needed for the trial was weighed out of the coal-bin and dumped in a separate pile on the floor, away from all other coals. From this pile coal was taken in barrows as required for running the test, and the weight of each barrow-load noted. This plan of keeping two separate accounts of the coal removed all chance of error in the amount of coal actually consumed, as at the close of each experiment the two accounts were balanced, and any error would have been detected at once. The second coal account has been taken as the basis for calculating the evaporation, adding to it of course the equivalent of the kindling-wood, which was taken at the rate of 0.40 pound of coal per pound of wood.

§ 12. Upon completing a trial fires were hauled and extinguished as rapidly as possible, the grates and ash-pits carefully cleaned, and all the coal, ashes, and clinkers hauled from under the boiler were sifted. The coal was carefully picked by hand and weighed separately. This amount of coal deducted from the amount of coal fired on the grates gives the amount of coal actually consumed. By deducting from the latter the amount of refuse (ashes and clinkers), the amount of combustible consumed was determined.

§ 13. The feed-water measuring apparatus consisted of two metallic tanks placed on separate platform scales with provision for filling from the hydrant. A Blake double-plunger feed-pump, supplied with steam from the boiler on trial, was placed between the tanks, and its suction-pipe was provided with a rubber hose, whereby the pump could be

made to take water at will from either tank. This pump was used on all the trials, and whenever it was attached to a new boiler precaution was taken to see that the feed-pipe was tight and that all other connections of the boiler to other pumps or injectors were broken off.

After filling a tank with water from the hydrant, its gross weight was noted; and after it had been pumped out almost dry the suction-hose of the pump was shifted to tank No. 2 (previously filled and weighed), and the gross tare of tank No. 1 was taken; the difference between the gross initial weight and the gross tare being the net weight of water pumped into the boiler. Tank No. 1 was then refilled and its gross weight again noted, when it stood ready to supply the pump as soon as tank No 2 should be emptied.

§ 14. The temperature of the feed-water was observed twice in each of the tanks. In the logs (Form 1) will be found the gross weights and gross tares of the tanks, together with the times at which hose was shifted, and the heights of water in the boiler at those times, also the temperatures of feed-water. The measurements of the feed-water and the running of the pump were intrusted to one assistant.

Another assistant had charge of the coal accounts, and also took half-hourly observations (given in Form 2 of logs) of the temperatures of the outside air, of the fire-room, steam, pyrometer, water-level, and steam pressure. This latter observation was taken from the gauge mentioned above, attached just below the stop-valve. A recording gauge was also attached to the boiler, and served to detect any negligence on the part of the man stationed on top of the boiler to regulate pressure. The barometric pressures given in the logs were not observed in the fire-room. Necessary data were kindly furnished by the Signal Station, U. S. A., and proper corrections have been made for level and temperature.

§ 15. The time was noted in every case when a tank of water was filled or a bucket of coal dumped (see Logs). This is an important precaution, as, by observing the differences of time, it becomes impossible to omit or duplicate a record, which is not an uncommon accident in using a simple tally.

§ 16. The records of the temperatures of steam, as shown in the logs and given by a mercury thermometer, are undoubtedly too low. It was found when a draft was blowing over the boiler that, by simply covering the stem of the thermometer, the mercury would rise 10° or 15° . It will be observed, however, that, although the temperatures shown by the thermometer fall short of the temperatures indicated by the calorimeter, the variations in both sets of records correspond.

§ 17. Anthracite coal from the Lea Colliery, Wilkesbarre, Pennsylvania, was used in all the trials, being the same as was supplied regularly to the Bureau of Machinery. It was nearly all uniform in size, and was taken directly from the pile without selection, so as to secure average working conditions. It proved to be of excellent quality, and, like many of the coals of the Wilkesbarre region, had an unusually low percentage of refuse for anthracite.

The two regular trials for economy and capacity were repeated with the Galloway boiler, using George's Creek bituminous coal of fair quality, that boiler being proportioned for the use of bituminous coal.

The firing was, in all cases, left to the judgment of the exhibitors.

§ 18. The percentages of refuse from the coal during the trials of different boilers are given in the following table, the quantities being modified slightly by the wood used in starting fires:

DESIGNATION OF BOILER.	PERCENTAGE OF REFUSE FROM COAL.		DESIGNATION OF BOILER.	PERCENTAGE OF REFUSE FROM COAL.	
	Capacity Test.	Economy Test.		Capacity Test.	Economy Test.
Wiegand	8.487	9.514	Lowe.....	10.640	11.286
Harrison	8.370	8.526	Babcock & Wilcox..	7.842	10.997
Firmenich	8.629	10.338	Smith.....	9.311	11.133
Rogers & Black....	7.868	9.836	Galloway.....	11.055	11.128
Andrews	9.428	10.319	Anderson.....	8.684	9.262
Root	9.674	10.485	Pierce.....	8.415	11.004
Kelly	8.676	9.009	Galloway (bitumi- nous coal).....	9.527	8.818
Exeter	9.254	11.405			

CALORIMETRIC TESTS.

§ 19. To determine the quality of the steam,—viz., whether it was moist, dry (saturated), or superheated,—portions were permitted to escape at regular intervals to a calorimeter, and employed to heat a known quantity of water. The general method has several times been employed for a similar purpose; but it was not thought necessary or practicable to use apparatus as delicate as that described by Professor Hirn (*Bulletin de la Société Industrielle de Mulhouse, 1868-1869*), or to condense all the steam, instead of utilizing it, on the more accurate plan developed by Professor Thurston (*American Institute Reports, New York, 1871-72*). The experiments were to be conducted at all hours of the day and night, and with the demand for celerity incident to the closing of the Exhibition; so it was considered advisable to use finely-graduated instruments of ordinary character, and

depend for greater accuracy upon the well-understood principle that the average of a large number of experiments practically eliminates errors not of a cumulative character, such as those arising from the want of unusually fine instrumental graduations.

§ 20. The calorimeter used consisted of a simple wooden barrel set on a platform scale,—arrangements being made whereby the barrel could be conveniently filled with cold water, and emptied by a cock at the bottom. A stirring apparatus was arranged in the bottom of the barrel, consisting of a small propeller operated by a handle on the top of a vertical shaft.

§ 21. The steam withdrawn from the calorimeter was in all cases taken from the vertical portion of the main steam-pipe nearest the boiler and just below the stop-valve regulating the delivery,—the connection being made by means of a piece of small pipe inserted through one side of the main pipe and extending horizontally across the opening. The small pipe was $\frac{3}{4}$ inch in diameter, and provided with perforations of greater area than the pipe directed downward towards the current of steam. The outer end of the pipe was reduced to $\frac{1}{2}$ inch diameter by an inserted nipple, to regulate the velocity of the flow, and connected by $\frac{3}{4}$ inch gas-pipe carefully felted, having an ordinary $\frac{1}{2}$ inch stop-valve at the end, to a hose 1 inch in diameter located near the calorimeter.

§ 22. In making an experiment, the initial weight and temperature of water in the calorimeter were observed, a little steam was blown to waste through the hose to heat the pipe, the hose was thrust into the water and the stop-valve opened wide, when the stirrer was operated and rapid observations of steam pressure noted, until the desired range of temperature in the calorimeter was obtained; then steam was shut off, the hose carefully removed, and final observations of temperature and weight of water in the calorimeter noted.

There were twenty-four such experiments made during each trial, the records of which are shown in Form 3 of the Logs, from which the quality of the steam may be obtained in the following manner:

§ 23. The water in the calorimeter of a known weight (W) [Col. 24—Col. 23] is raised from the initial temperature (t) [Col. 26] to the final temperature (t_1) [Col. 27], so on the basis that the heat absorbed, expressed in heat-units, is measured by the difference in temperature (which is very nearly correct, as referred to hereafter), the number of heat-units imparted to the calorimeter is expressed by the product of the weight in pounds by the range in temperature [$W(t_1 - t)$]. This number of heat-units is derived from the steam received from the boiler and condensed in the calorimeter, the weight

[w] of which is shown by the increased gross weight [Col. 25—24]. This condensed steam imparts to the calorimeter: first, its sensible heat, measured by its weight multiplied by the difference in the temperature of the steam [T] due to the pressure, and that finally obtained in the calorimeter [$w(T-t_1)$]; second, the latent heat of the portion evaporated; and, third, in some cases, the superheat, which has raised the temperature of the steam above that due to the pressure.

§ 24. If from the total heat imparted to the calorimeter [$W(t_1-t)$] we subtract the sensible heat [$w(T-t_1)$] of the water added, the remainder expresses the number of heat-units available for evaporation from the actual steam pressure, which result, divided by the latent heat (l), due to that pressure, gives the number of pounds of water (x) which the heat in the steam is capable of evaporating at such pressure. Hence, using the symbols set forth above in the parentheses, we have—

$$x = \frac{W(t_1 - t) - w(T - t_1)}{l}$$

§ 25. The quality of the steam (Q), when either moist, dry (saturated), or superheated, may be conveniently and clearly expressed by comparing the amount of heat it contains with that in dry or saturated steam. We have, then,—

$$Q = \frac{x}{w} = \frac{W(t_1 - t) - w(T - t_1)}{lw}$$

When, therefore, the steam is moist the value of Q is a decimal which represents the proportion of the steam which was actually evaporated; for instance, if, $Q = .95$, ninety-five hundredths of the apparent evaporation was actually evaporated, and the remaining five per cent. represents the moisture in the steam. When the steam is dry (saturated), $Q = 1$, and when steam is superheated, Q is greater than unity. In the latter case the excess represents the heat available for superheating, or the additional quantity of water which would have been evaporated had it been present. We thus have a basis of comparison for the quality of steam, whether moist or superheated, which expresses its comparative value under all conditions. For instance, the quality may be 95 per cent., or 102 per cent. of the standard, which is dry or saturated steam, which numbers represent accurately the quantity of water at a given steam pressure which the heat actually imparted would evaporate into dry steam of the same pressure.

§ 26. From the above we may derive also—

When $Q < 1$, percentage of water primed $= 100(1 - Q)$.

When $Q > 1$, number of degrees steam is superheated $= \frac{(Q-1)I}{.48} = 2.0833I(Q-1)$.

§ 27. Since the specific heat of steam varies slightly at different temperatures, greater accuracy is obtained in making calculations by using tables in which this is taken into account, which has been done for the results hereinafter set forth. The several experiments have been calculated separately, and the average based on the proportional quantities of steam withdrawn from the boiler for each experiment, compared with the totals of such quantities.

§ 28. The records in nearly all cases have been found to correspond well among themselves, only one case arising where any portion has been rejected for manifest inconsistencies. By referring to column 25 of calorimeter records for the capacity test of the Exeter Boiler, it will be seen that in seven instances out of the twenty-four it apparently required ten pounds more steam to produce a given heating effect than in the other cases, thus showing in some instances nearly 70 per cent. priming, which is impossible, as no water would have remained in the boiler after a short time. Moreover, there is no gradation in the results, so the discrepancy is evidently due to an error of the assistant in reading the second figure on the scale, and represents a not uncommon experience among investigators. The seven records mentioned have been rejected in making the calculations, also the last similar one of the economy test of the same boiler, the logs, however, being retained in their original shape, so that others may draw their own conclusions.

§ 29. The weight of the calorimeter-barrel given in column 23, Form 3, logs, is the mean of two observations taken at the beginning and end of trial; the different weights on different days are due to differences in amount of moisture absorbed by the wood in the various locations in respect to the several boilers. The actual weight of water in the calorimeter has, in making calculations, been increased in all cases one pound, to allow for the moisture on the inner surface of the barrel in weighing and for the influence of the stirring-apparatus, which latter is measured by its weight multiplied by the specific heat of iron.

TABLES OF RESULTS.

§ 30. The results of the experiments are set forth in the tables,—§ 50-51,—and it is believed will be readily understood with little explanation.

§ 31. From the total quantity of water pumped into the boiler and

apparently evaporated, line 21, the evaporation per hour, based on the actual amount of heat in the steam, line 22, has been ascertained for each trial by simply multiplying by the quantity expressing the quality of the steam, line 18, and dividing by the duration of the trial in hours, line 3.

§ 32. The evaporation during the several experiments took place at different pressures and temperatures, using fuel differing in amount of refuse, and consequently in calorific value. The water apparently evaporated per pound of the coal used is in each case given in line 24. In all subsequent lines the quality of steam has been considered. In lines 25, 26, and 27 the economical evaporations for all the boilers are compared on the same basis.

§ 33. Line 25 shows the water evaporated for each pound of the combustible portion of the coal at a steam pressure of 70 pounds from a temperature of 100° , from which the evaporation under other conditions may be conveniently obtained. Line 26 shows the evaporation per pound of combustible at atmospheric pressure from temperature 212° . This line has been prepared so that the results of the experiments may be conveniently compared with those obtained with other boilers at different pressures.

§ 34. Line 27 shows what we have termed the Commercial Evaporation, and represents, on a uniform basis for all the boilers, the quantity of water which each will evaporate under ordinary working conditions per pound of anthracite coal of average quality. The pressure of seventy pounds has been selected as representing fair average practice, and the evaporation will be little different for considerable differences in pressure. The temperature of feed has been assumed at 100° , as few boilers use cold water, and 100° is easily obtained with condensing engines, and is not greatly exceeded when inefficient heaters are used with non-condensing engines. When a temperature of 200° can be depended upon, the commercial evaporation given would be increased 10 per cent., and proportionally for intermediate temperatures. For the purpose of comparison, anthracite coal is assumed to have $\frac{1}{8}$ refuse, which is as little as can be depended upon in ordinary practice.

§ 35. Line 34 shows the estimated Horse-Power of the several boilers, on the basis that the evaporation of thirty pounds of water is required per horse-power per hour, the results being derived from line 23, showing evaporation at steam pressure of 70 pounds from temperature of 100° .

DESCRIPTION OF THE BOILERS.

§ 36. Illustrations of the boilers are shown in Exhibit A, at the close of this report. The Wiegand boiler consists of ten sections connected by one steam-drum and one feed-pipe; each section consists of a cast-iron tube-head, made in the form of a double pipe with connecting necks, into the bottom of which are screwed, in two rows of nine each, eighteen wrought-iron vertical tubes closed at their lower ends by cast-iron caps, each tube being 4 inches in diameter and 5 feet 4 inches long, including the cap. Within each of the tubes is arranged a smaller tube, resting at its lower end on the cap which closes the outer tube, and the upper end of the inner tube protrudes inside the tube-head, through and beyond a perforated baffle-plate. The cast-iron cap closing each outer tube is shaped so as to permit the free flow of water from the inner tube to the annular space between that and the outer tube. The heated gases striking the outer tube cause an upward current in the annular space, and consequently a downward current in the inner tube. The steam-drum is of wrought-iron, and its ends and those of the tube-heads are built in the brick-work and support the boiler. The grate is directly under the tubes; the flames and heated products of combustion rise vertically between the tubes and tube-heads; and, circulating around the steam-drum, half of which is superheating surface, pass to the chimney flue at the side.

§ 37. The Harrison boiler consists of eight sections or slabs built up of hollow cast-iron spheres, each 8 inches in outside diameter, connected by curved necks. The spheres are cast in groups of 2 and 4, and are connected by rebate joints. The groups are held together by bolts extending through the spheres and necks the entire length of sections, provided over caps at the end with external nuts. Each section or slab contains two rows of 12 spheres, four rows of 13, and two rows of 3, making 82 spheres to a slab. The slabs are connected to one feed-pipe and one steam-pipe by a series of short fittings and pipes with spherical joints forming a flexible connection, which facilitates erection and permits expansion. Between the slabs and about at the water-line are placed horizontal cast-iron T bars, which prevent the direct action of the hot gases on the steam-heating surface. The slabs are set side by side at the angle shown, and are supported on suitable cast-iron rails or bars.

§ 38. The Firmenich boiler is provided with a central grate, at the sides of which are set in the brick-work two drums connected with two elevated drums by wrought-iron tubes 3 inches in diameter and

12 feet long, slightly inclined from the perpendicular, the ends of which are expanded in the drums. There are 50 of these tubes on each side, set in two rows, and arranged longitudinally in three divisions, located in different compartments of the brick-work. The first and larger compartment contains the grate from which the products of combustion pass upward, between, and along the tubes, and over the top of the compartment-wall; thence downward in two separate flue-shaped passages in the brick-work, along the second division of 12 tubes on each side; thence at either side through the bottom of the next compartment-wall and upward in rear flues along the last division of 4 tubes on each side. The currents from the two sides unite at the top and pass across the ends of the drums to the chimney. The lower drums are connected at the rear; the two upper drums are connected to a third central steam-drum by short necks. The whole boiler is inclosed in brick, as shown.

§ 39. The Rogers & Black boiler is composed of a vertical shell suspended over the grate by means of 4 wrought-iron brackets resting on the side-walls, and is provided with 72 external tubes, 2 inches in diameter, arranged vertically outside the shell in two circles; concentric therewith, the ends of the tubes being bent inward, as shown, and expanded in the shell. The products of combustion circulate around the shell and between the tubes, and escape at a side flue. On the top of the vertical shell is attached a horizontal steam-drum.

§ 40. The Andrews boiler is of the double return marine tubular type, with external sheet-iron connections for directing the products of combustion. The shell is rectangular with semi-cylindrical top. From the furnace, which is inclosed in the boiler, the products of combustion pass through short tubes, crossing rear water-space to a lower compartment in rear connection; return through the tubes above the furnace and below the water-level to front connection, and, making a second return through tubes in the steam-space, escape through the upper compartment of rear connection to the chimney. This boiler was designed to obtain, in portable form, large power in small space, and had, it is understood, been frequently used in wrecking operations.

§ 41. The Root boiler consists of 160 wrought-iron tubes, 4 inches in diameter, and 8 feet 10 inches long, set in a group at an angle of about 20° from the horizontal, and inclosed at the top and sides in brick-work. Upon each end of each tube is screwed a cast-iron chamber, with small openings in the ends, and provided with a square flange. The several chambers are laid upon each other, so that the tubes are staggered, and the ends connected by hollow triangular

caps, shaped so as to make shallow socket-joints, packed with rubber around the openings. The caps are held in place by simple crow-feet. A steam-drum is attached to the boiler, and connected with the upper row of tubes by short pieces of $2\frac{1}{2}$ -inch pipe, the water-level being carried about 22 inches below them. The course of the products of combustion may be readily traced on the drawing.

§ 42. The Kelly boiler consists of seven sections, connected to one feed-pipe and one steam-drum; in each section 10 wrought-iron tubes, each 3 inches in diameter, and 9 feet $9\frac{1}{2}$ inches long, in two vertical rows of 5 each, are screwed in a cast-iron tube-head at the front, and incline slightly downward towards the rear, at which end they receive support, and are closed by caps. Diaphragm plates are set inside the tubes to secure circulation of the water therein. Above the water-line are secured shorter horizontal tubes, with rear ends closed, which are intended to superheat the steam. The main steam-drum, which is not exposed to the heat from the fire, is connected to a drum or water-heater located back of the tubes, inside of the walls. A return-pipe connects this drum to a main feed-pipe, joining the several sections.

§ 43. The Exeter boiler consists of hollow, rectangular, cast-iron, slab-shaped sections, set transversely, with twelve oblong openings in two horizontal rows through each section; there are 27 such sections, placed one in the rear of the other, and connected through short side pipes to one steam- and one feed-pipe, thus forming a complete boiler. Two of these boilers are placed side by side over one grate. The spaces between the sections are closed at the centre by horizontal partitions. The gases from the grate pass to the rear of the boiler through the lower rows of passages in the sections, and return through the upper rows, then pass to the rear again over the top of the sections, and escape to the uptake. The water-level is carried at about two-thirds the height of the sections; the steam-drum is not exposed to the heat. The feed-pipes of the two boilers are connected, but provided with independent checks and valves for shifting the feed.

§ 44. The Lowe boiler is an ordinary cylindrical tubular boiler, 4 feet in diameter and $18\frac{1}{2}$ feet long, containing 46 tubes, each 3 inches in diameter and 15 feet long, with a chamber or connection in the front end of the boiler, the rear of which forms the front tube sheet. The bridge-wall back of the grate is extended up to the shell. The heated gases pass through side openings, through water-space, into the front chamber or connection previously mentioned, thence through the tubes to the rear of the boiler, then in a return flue along the lower half of the shell to the rear of the bridge-wall, when they rise

through two side flues, and, circulating around the upper half of the shell and a superheating drum, escape to the uptake.

§ 45. The Babcock & Wilcox boiler contains a group of 98 tubes, each $3\frac{1}{2}$ inches in diameter and 15 feet 9 inches long, set at an angle of about 15° from the horizontal, in 14 horizontal rows, with 7 tubes in each row. The tubes in each vertical row are expanded at both ends in tube-heads to form sections, the heads being shaped to stagger the tubes. Openings are provided opposite each tube for cleaning. The sections are connected in groups of seven, at front and rear, to two horizontal drums. The water-level is maintained near the centre of these drums, and their lower portions are exposed to the heat. The two drums are connected by a horizontal steam-drum, as shown. Flanges on the tubes form a support for two fire-brick partitions, which, with the deflecting walls shown, cause the heated products of combustion to pass between the tubes three times before reaching the chimney-flue.

§ 46. The Smith boiler is an ordinary cylindrical fire tubular boiler, with additional heating surface applied by means of a setting. The bridge-wall is of cast-iron, hollow, and water-tight, and is connected with the feed-pipe. From the bridge-wall a set of pipes run horizontally under and back of the boiler, and connect through elbows to short vertical tubes screwed into a larger horizontal pipe located back of the shell and connected thereto. In addition to the above two cast-iron pipes run along either side of and below the grate, and are connected with the water-space in the shell. In the latter are attached on either side a series of vertical conical castings, bulb-shaped at their tops, with a small wrought-iron pipe in each as an outlet for steam, and the several small steam-pipes are connected together, and to the steam-space of the main shell.

§ 47. The Galloway boiler is constructed of steel, and consists of a shell 7 feet in diameter and 28 feet long. There are two grates located in cylindrical flues 33 inches in diameter and 7 feet 6 inches long. Beyond the grates the flues join in one elliptical flue extending to the rear of the boiler, and crossed by 30 vertical conical water-tubes known as "Galloway Tubes." The heated gases from the furnaces pass around the conical tubes and through the elliptical tube to the rear of the boiler, return to the front along the sides of the shell below the water-line, and, passing to the rear again under the centre, escape to the uptake.

§ 48. The Anderson boiler is composed of 14 sections connected together above and below the water-line. Each section contains 9 wrought-iron tubes 3 inches in diameter and 10 feet long, which are

nearly horizontal and arranged in a vertical row. The four lower tubes are secured at their front ends to a cast-iron chamber and rise a little from front to rear. The front ends of the five upper tubes are similarly attached to an upper chamber, and slope a little from front to rear. The rear ends of all the tubes in each section are united by a manifold 3 inches in diameter. The lower front chambers are connected at their lower ends, and the front upper chambers at their upper ends. A vertical mud-drum is placed near the boiler front outside the brick-work, its lower end being attached to the lower or water-chambers, and its upper end to the steam-chambers. A steam-drum is attached on the top of the boiler outside of the brick-work. Slabs are so disposed as to form a partition above the 4 lower tubes of the several sections. The hot gases are therefore compelled to flow towards the rear end of the boiler in contact with the lower tubes, and to return in contact with the upper tubes nearly to the front end, where they escape to the uptake.

§ 49. The Pierce boiler consists of a cylinder revolved directly over the grate on suitable trunnions. The heated gases envelop the cylinder and enter one end of an annular row of tubes in the shell, and traversing the whole length of the boiler, return through another row of tubes concentric with the first, and escape to the chimney. Cups are secured around the tubes of the outer annular row to catch the water whenever the tube is lifted above the water-line by the revolving of the shell, and thus prevent overheating. The feed-water is introduced, and steam taken from the boiler, through the trunnions.

§ 50 B.—RESULTS OF THE CAPACITY TRIALS OF THE STEAM-BOILERS.

I	DESIGNATION OF BOILER.	EXETER. H	LOWE. I	BARBOCK & WILCOX. J	SMITH. K	GALLO- WAY. L	WAL- BURN- MINOUS. T	ANDER- SON. M	PIERCE. N
		Oct. 12. 8	Oct. 14. 8	Oct. 18. 8	Oct. 21. 8	Oct. 26. 8	Oct. 31. 8	Nov. 7. 8	Nov. 10. 8
2	Date of trial.....	1876							
3	Duration of trial.....	Hours							
4	AVERAGE PRESSURES.								
5	Steam pressure in boiler above atmosphere.....	70.00	70.00	70.00	70.21	70.09	70.18	70.00	70.00
6	Atmospheric pressure (see "Barometer," Col. 20, logs).....	14.82	14.55	14.62	14.58	14.66	14.73	14.58	14.62
7	Total steam pressure.....	84.82	84.55	84.62	84.79	84.75	84.91	84.58	84.62
8	AVERAGE TEMPERATURES.								
9	Of external air.....	57.31	67.06	63.25	70.06	52.20	58.06	56.65	46.71
10	Of fire-room.....	83.00	93.00	90.13	78.06	68.23	71.06	56.65	46.71
11	Of steam.....	306.00	308.65	309.44	309.62	309.68	310.18	320.47	310.88
12	Of uptake.....	438.12	339.71	472.81	435.06	322.18	383.00	534.00	455.62
13	Of feed-water.....	66.50	66.16	57.60	58.16	56.04	53.95	54.75	52.15
14	COAL, ETC.								
15	Total amount of coal consumed, including equivalent of wood.....	3,290.50	1,898.50	5,407.00	3,190.10	3,699.70	3,285.55	4,191.70	2,071.20
16	Total refuse.....	304.50	297.00	424.00	297.00	409.00	313.00	364.00	174.30
17	Total combustible.....	2,986.00	1,606.50	4,983.00	2,893.10	3,290.70	2,972.55	3,827.70	1,896.90
18	Coal consumed per hour.....	411.31	237.31	675.87	398.76	462.46	410.69	523.96	258.90
19	Combustible per hour.....	373.25	212.06	622.87	361.64	411.34	371.57	478.46	237.11
20	Equivalent weight of coal per hour, with one-sixth refuse.....	447.90	254.47	747.45	433.97	493.61	445.88	574.15	284.53
21	RESULTS OF CALORIMETRIC TESTS.								
22	Quality of steam. Heat-units in dry (saturated) steam being unity.....	.952	1.005	.991	1.0035	1.006	.994	.997	.999
23	Percentage of moisture in steam.....	4.868	9.888	.940	6.444	11.682	.624	.307	7.149
24	Number of degrees superheated.....								
25	WATER.								
26	Total weight of water pumped in boiler and apparently evaporated.....	26,278.75	15,959.75	43,535.75	28,817.00	30,680.75	28,998.75	30,704.75	16,805.50
27	Water evaporated per hour, corrected for quality of steam.....	3,126.91	2,005.58	5,390.81	3,614.62	3,860.07	3,606.22	3,820.31	1,950.51
28	Equivalent evaporation per hour, steam pressure 70 lbs., from temp. 100° F.....	3,238.42	2,077.66	5,596.90	3,751.11	4,013.16	3,752.00	3,982.39	2,034.65
29	ECONOMIC EVAPORATION.								
30	Water apparently evap. per lb. of coal from actual pressure and temperature.....	7.986	8.466	8.052	9.033	8.293	8.826	7.325	8.114
31	Water evaporated per pound of combustible at steam pressure of 70 pounds from temp. 100° F., corrected for quality of steam.....	8.676	9.710	8.986	10.373	9.756	10.098	8.323	8.581
32	Water evap. per lb. of combustible at atmospheric press. and temp. 212° F.....	9.974	11.163	10.330	11.925	11.216	11.609	9.568	9.865
33	COMMERCIAL EVAPORATION (see § 34).								
34	Water evap. per lb. coal, with $\frac{1}{4}$ refuse, 70 lbs. pressure, from temp. 100° F.....	7.230	8.091	7.487	8.644	8.130	8.415	6.936	7.151
35	RATE OF COMBUSTION.								
36	Consumption of coal per hour.....	14.930	11.310	16.797	17.359	13.711	12.386	15.949	11.381
37	Coal assumed, with one-sixth refuse.....	.287	.338	.376	.376	.523	.523	.515	.381
38	Per square foot of grate-surface.....	104.104	129.173	83.050	133.990	61.024	55.065	53.162	245.294
39	Per square foot of total heating surface.....								
40	Per square foot of least area for draft.....								
41	RATE OF EVAPORATION.								
42	Water evaporated from 70 } Per square foot of grate-surface.....	107.947	92.338	125.773	150.044	111.477	104.222	110.622	81.386
43	at same pressure and temper- } Per square foot of total heating surface.....	2.072	2.757	3.339	3.251	4.707	4.401	3.572	5.884
44	ature of 100° } Per square foot of least area for draft.....	753.121	1,054.619	621.878	1,157.689	501.019	468.414	368.740	1,754.009
45	ESTIMATED HORSE-POWER.								
46	On basis of 30 lbs. water evap. per H. P. per hour, 70 lbs. press., temp. 100° F.....	107.95	69.25	186.56	125.04	133.77	125.07	132.75	67.82

§ 51 A.—RESULTS OF THE ECONOMY TRIALS OF THE STEAM-BOILERS.

DESIGNATION OF BOILER.													
	WIEGAND. A	HARRISON B	FIR- MENICH. C	ROGERS & BLACK. D	ANDREWS. E	ROOT. F	KELLY. G						
1	Sept. 22. 8	Sept. 21. 8	Sept. 26. 8	Sept. 30 and Oct. 1. 8	Oct. 3. 8	Oct. 6. 8	Oct. 9. 8						
2	Date of trial.....												
3	Duration of trial.....												
4	Steam pressure in boiler above atmosphere.....												
5	Atmospheric pressure (see "Barometer," Col. 20, logs).....												
6	Total steam pressure.....												
7	AVERAGE TEMPERATURES.												
8	Of external air.....												
9	Of fire-room.....												
10	Of steam.....												
11	Of uptake.....												
12	Of feed-water.....												
13	COAL, ETC.												
14	Total amount of coal consumed, including equivalent of wood.....												
15	Total refuse.....												
16	Total combustible.....												
17	Coal consumed per hour.....												
18	Combustible per hour.....												
19	Equivalent weight of coal per hour, with one-sixth refuse.....												
20	RESULTS OF CALORIMETRIC TESTS.												
21	Quality of steam. Heat-units in dry (saturated) steam being unity.....												
22	Percentage of moisture in steam.....												
23	Number of degrees superheated.....												
24	WATER.												
25	Total weight of water pumped in boiler and apparently evaporated.....												
26	Water evaporated per hour, corrected for quality of steam.....												
27	Equivalent evaporation per hour at steam pressure of 70 pounds from temp. 100° F.....												
28	ECONOMIC EVAPORATION.												
29	Water apparently evaporated per pound of coal from actual pressure and temperature.....												
30	Water evaporated per pound of combustible at steam pressure of 70 pounds from temp. 100° F., corrected for quality of steam.....												
31	Water evaporated per pound of combustible at atmospheric pressure and temp. 212° F.....												
32	Water evap. per lb. of coal, with one-sixth refuse, at pressure of 70 lbs. from temp. 100° F.....												
33	RATE OF COMBUSTION.												
34	Consumption of coal per hour.....												
35	Coal assumed, with one-sixth refuse.....												
36	Per square foot of grate-surface.....												
37	Per square foot of total heating surface.....												
38	Per square foot of least area for draft.....												
39	RATE OF EVAPORATION.												
40	Water evaporated from 70°.....												
41	Per square foot of total heating surface.....												
42	Per square foot of least area for draft.....												
43	ESTIMATED HORSE-POWER.												
44	On basis of 30 lbs. of water evap. per H. P. per hour at 70 lbs. pressure and temp. 100° F.....												

§ 51 B.—RESULTS OF THE ECONOMY TRIALS OF THE STEAM BOILERS.

[illegible]

§52. GOVERNING PROPORTIONS OF THE BOILERS TESTED.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
LETTERS FOR REFERENCE.	DESIGNATION OF BOILER.	GRATE SURFACE.	HEATING SURFACE.			AREA FOR DRAFT BETWEEN HEATING SURFACES.	RATIO—			WATER SPACE.	STEAM SPACE.	RATIO GRATE TO WATER SPACE.	RATIO GRATE TO STEAM SPACE.	HEIGHT OF CHIMNEY ABOVE GRATES.
			Water.	Steam.	Total.		Grate to Total Heating Surface.	Draft Area to Grate.	Draft Area to Total Heating Surface.	Cubic Feet.	Cubic Feet.	Cubic Feet per Sq. Ft. Grate.	Cubic Feet Steam Space per Sq. Ft. Grate.	Feet.
A	Wiegand.....	42.00	1289.70	49.67	1339.37	Between tube-heads..... 5.00*	31.89	8.40	267.87	181.36	44.18	4.32	1.05	84.75
B	Harrison.....	23.00	627.00	274.00	901.00	Below T-bars... 6.54*	39.17	3.52	137.77	54.09	23.72	2.35	1.03	84.75
C	Firmenich.....	15.41	1001.10	30.00	1031.10	At rear..... 8.5	66.91	5.14	343.70	145.12	92.20	9.42	5.98	84.75
D	Rogers & Black....	21.00	.....	.....	399.75	1st flues..... 6.49	19.04	.....	.....	36.15	24.85	1.72	1.18	84.75
E	Andrews.....	18.42	288.04	218.36	506.40	2d contraction 7.50	27.49	9.80	269.36	80.74	25.45	4.38	1.38	84.75
F	Root.....	42.00	1451.77	146.66	1598.43	2d flues..... 3.00*	38.06	8.33	317.15	116.68	45.69	2.78	1.09	84.75
G	Kelly (h. s. of 1/2 heater inc.....)	27.50	575.06	60.48	635.54	1..... 2.30	23.11	6.74	155.77	58.17	27.97	2.12	1.02	84.75
H	Exeter.....	30.00	1005.06	557.94	1563.00	2..... 1.88*	52.10	6.98	363.49	83.77	44.60	2.79	1.49	84.75
I	Low.....	22.50	687.88	65.76	753.64	1..... 5.04*	33.50	11.42	382.56	140.18	59.90	6.23	2.26	84.75
J	Babcock & Wilcox	44.50	1676.32	0.00	1676.32	Openings in shell..... 2.14	37.67	4.94	186.26	229.00	137.85	5.15	3.10	84.75
K	Smith.....	25.00	1146.43	7.57	1154.00	Tubes..... 1.97*	46.16	7.72	356.17	136.12	127.39	5.44	5.10	84.75
L	Galloway.....	36.00	822.54	0.00	822.54	Side flues..... 1.80	23.68	4.49	106.43	562.91	169.12	15.64	4.70	89.50
M	Anderson.....	36.00	630.00	485.00	1115.00	3..... 9.00*	30.97	3.33	103.24	66.90	55.75	1.86	1.55	70.00
N	Pierce.....	25.00	.....	.....	349.33	Int. flue..... 3.24*	13.97	21.55	301.15	20.11	43.11	.80	1.72	70.00
						Bot. flues..... 8.04								
						Over bridge..... 10.8*								
						End of plate..... 11.0								
						Return..... 15.7								
						2..... 1.16*								

§ 53. The awards of the Judges were not based upon the trials; in fact, the latter were not commenced until the awards had been made by another committee of the same group. This report has been confined to a statement of what actually took place during the trials, without expressing opinions upon the all-important questions of the value, but more particularly the trustworthiness of the different mechanical details and arrangements employed by the various exhibitors. Many of these questions can only be settled by long practical use, under different circumstances as to management and the kind of fuel and water used.

§ 54. All the boilers of which tests were completed remained tight and in good working condition throughout except that one of the cast-iron caps on a tube in the Wiegand boiler cracked while a trial was in progress; after repairs, the entire trial was repeated.

A few slight leaks in some of the boilers were stopped before the tests commenced; and for one boiler, not herein mentioned, which could not be made tight, the tests were abandoned.

§ 55. The feed-water measuring-apparatus and the thermometers, including the fine thermometer needed for calorimetric observations, were loaned by Mr. Lloyd S. Wiegand, who evinced great interest in the experiments. Ashcroft's steam-gauges were employed, and were tested several times during the progress of the trials and found correct. Mr. Edson loaned one of his recording-gauges, which agreed perfectly with the other gauges, indicating even the small variations of pressure due to taking the calorimetric observations. Mr. Edward Marsland loaned one of his water-meters, which was used on the water-pipe from the hydrant to the measuring-tanks, and afforded a check on the weighing of the feed-water. The amount registered by the meter agreed within two per cent. with the amount measured in the tanks, the errors at times being as low as two-tenths of one per cent. Adams's shaking grates, used in the Firmenich, Root, and Babcock & Wilcox boilers, operated satisfactorily. The platform scales loaned by Fairbanks & Co. were tested before and after the experiments and found correct.

§ 56. Messrs. W. H. Weightman, A. R. Wolff, M.E., and G. C. Henning, M.E., assisted in making the final calculations herewith presented.

Very respectfully,

CHARLES E. EMERY,
CHARLES T. PORTER,
JOSEPH BELKNAP,

Committee on Boiler Trials of the Judges of Group XX.

TRIAL OF THE HOADLEY PORTABLE ENGINE.

HORATIO ALLEN, ESQ.,

Chairman Group XX., International Exhibition, Philadelphia.

DEAR SIR,—The following is a report of trials made by this Committee of the portable engine exhibited by the J. C. Hoadley Company, of Lawrence, Massachusetts, on the 17th of September, 1876:

§ 57. The boiler is of the locomotive type, 16 feet long, with shell 40 inches in diameter. The upper plates are one-half inch thick, the lower ones three-eighths inch; the engine is secured to the top of the boiler, the upper plates being made heavier and stiffened to support the load. The cylinder is 14.56 inches in diameter and of 19.91 inches stroke, and is provided with a steam-jacket, serving also as the steam-drum of the boiler, and carrying the safety-valve. The main crank is double; the pillow-blocks on either side of it are made in one piece, with a saddle fitted upon and double riveted to the boiler, which saddle at its centre extends through an opening in the shell, thus giving clearance for the connecting-rod with the main shaft and cylinder at a reduced distance above the boiler. There are two balance-wheels, respectively 6 and 7 feet in diameter. The steam is distributed by Davis's patent piston-valve, made with considerable lap to obtain expansion, and operated by an eccentric, which is attached to a slide, and arranged so that its centre will be shifted at right angles to the direction of the main crank in a line advanced beyond the centre of the main shaft sufficiently to give the lead. The shifting is accomplished by a centrifugal governor attached directly to the main shaft inside one of the balance-wheels, and consisting of weights controlled by elliptical springs. The motion imparted to the valve resembles that given by the stationary link motion.

Further details and general dimensions of the engine may be obtained from the tables and illustrations. (Figs. 65, 66, 67, and 68.)

§ 58. Previous to the trial steam was raised with fuel which was not weighed, the engine remaining at rest; the fire was then hauled out and renewed with weighed fuel, when, in due time, the engine was started, kept in operation for six hours and two minutes, when fires were again hauled, and all the remaining combustible credited. During the trial the water was weighed in the tanks, the revolutions of the engine noted by a register, and diagrams were taken every 20 minutes; the engine was controlled by a brake, which served also as a dynamometer, the indications of which were regularly noted. The

brake consisted simply of iron bands surrounding one of the fly-wheels, faced inside with wooden blocks 3 by 5 inches, and provided with a tightening screw on one side and a lever on the other, to which were attached the weights and the usual regulating cylinder. A specimen indicator diagram is herewith presented. (Fig. 68.)

GENERAL DIMENSIONS.

<i>Engine.</i>	
Diameter of cylinder	14.56 inches.
“ “ piston-rod	2.375 “
Length of stroke	1.66 feet.
Capacity of clearances and passages in fractions of stroke	.091 “

<i>Boiler.</i>	
Length of boiler	16.0 feet.
Diameter of shell inside	40.0 inches.
Length of fire-box inside	54.0 “
Width “ “	34.0 “
Height “ above grates (whole height 48 inches)	44.0 “
Number of tubes	80.0
Diameter of tubes outside	2.25 “
Length of tubes (between sheets)	113.0 “
Heating surface in fire-box above top of the grates . .	60.5 sq. feet.
“ “ “ tubes	394.5 “
“ “ “ smoke-box	6.5 “
“ “ aggregate	461.5 “
Area of fire-grate 54 by 34 inches	12.75 “
Ratio of heating surface to fire-grate area	36.20 “

RESULTS OF TRIAL.

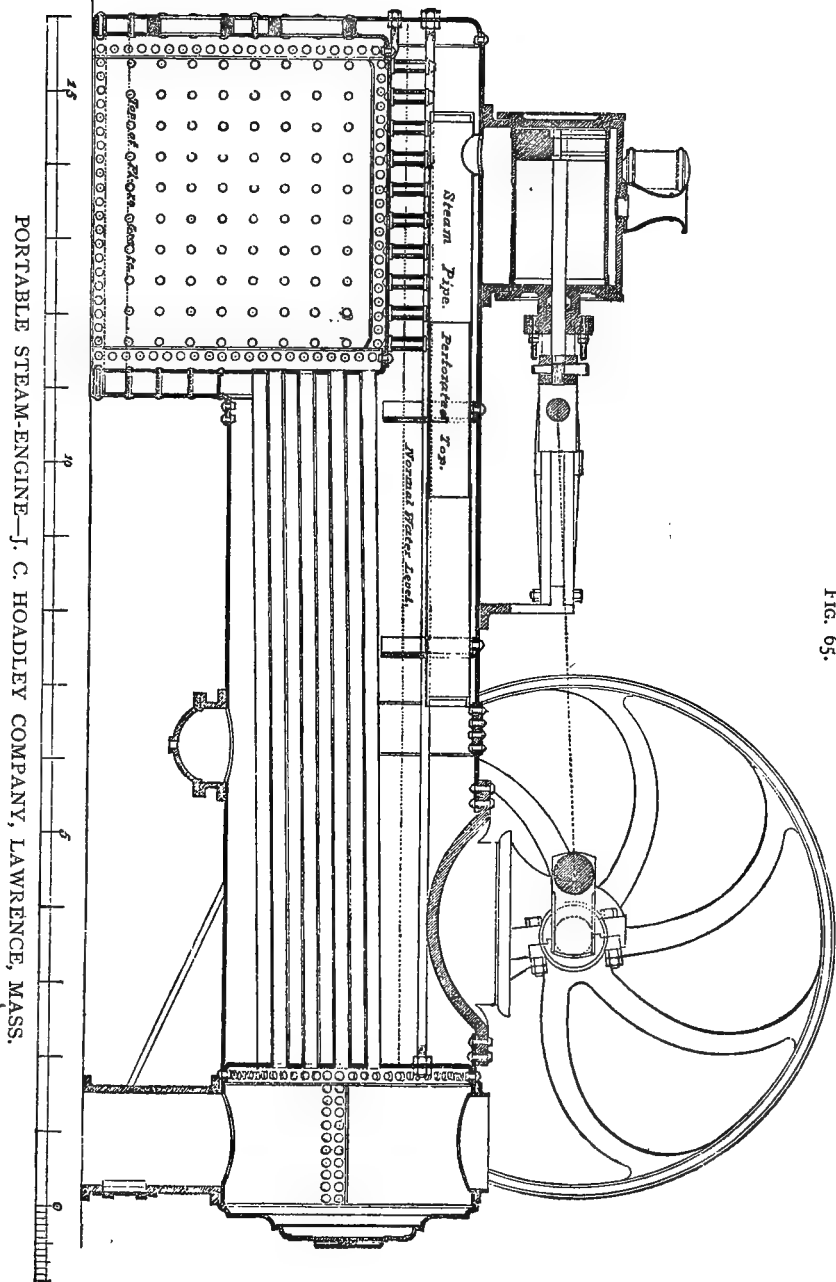
Duration of trial	6 hours 2 min.
Average steam pressure in boiler	124.61 pounds.
Average cut-off in fractions of stroke . . . . .	.1765
Ratio of expansion	4.2
Average temperature of external air	65.89 deg. Fah.
“ “ “ engine-room	79.92 “ “
“ “ “ uptake	534.08 “ “
“ “ “ feed-water entering heater	73.00 “ “
“ “ “ “ “ boiler	183.00 “ “
“ “ “ steam	336.54 “ “
Total revolutions during trial	45,597.00
Average revolutions per hour	7,557.60
“ “ “ minute	125.96
“ initial pressure in cylinder, total	127.55 pounds.
“ “ “ “ to point of cut-off, total	122.34 “
“ final pressure in cylinder	27.64 “
“ total “ on piston	63.765 “
“ back “ “	25.275 “
“ net effective pressure on piston	38.49 “
Point of cushioning in fractions of stroke . . . . .	.40
Indicated horse-power	80.29

Dynamometer horse-power	72.72	
Power expended in friction of engine when loaded	7.57	
Power required to operate engine at its normal speed when unloaded, per indicator	5.80	
Total weight of feed-water pumped in boiler	12,404.5	pounds.
Average water per hour pumped in boiler	2,057.13	"
“ “ “ per indicator	1,555.97	"
Total amount of coal consumed	1,621.	"
Average “ “ “ per hour	268.67	"
Coal consumed per square foot of grate per hour	21.07	"
Refuse from coal	191.5	"
Percentage of refuse from coal	11.8	per cent.
Total combustible	1,429.5	pounds.
Combustible per hour	236.95	"
Water per indicated horse-power per hour by measurement	25.61	"
“ “ dynamometer “ “ “	28.27	"
“ “ total per “ “ “	15.47	"
“ “ indicated “ “ indicator	19.38	"
“ “ dynamometer “ “ “	21.40	"
“ “ total “ “ “	11.71	"
Coal per indicated horse-power per hour	3.35	"
“ “ dynamometer “ “	3.69	"
“ “ total “ “	2.02	"
Combustible per indicated horse-power per hour	2.95	"
“ “ dynamometer “ “	3.26	"
“ “ total “ “	1.78	"
Number of pounds of water evaporated per square foot of heating surface per hour	4.64	"
Number of pounds of water evaporated per pound of coal	7.65	"
Number of pounds of water evaporated per pound of com- bustible	8.68	"
Equivalent evaporation per pound of coal at actual steam pressure from temperature 212°	9.096	
Equivalent evaporation per pound of combustible at atmos- pheric pressure from temperature 212°	10.32	

§ 59. Preparations for the trial were made by Mr. J. C. Hoadley in consultation with the Committee. Two of the members of the Committee were present while the trials were in progress, and two of the assistants engaged for the boiler experiments were detailed to take the observations. Before the Committee had the leisure to attend to the matter Mr. Hoadley, who had duplicate indicator diagrams and records, made elaborate calculations, which were checked and found correct, and the portions of greatest general interest have been re-arranged and are herewith presented.

CHARLES T. PORTER,
JOSEPH BELKNAP,
CHAS. E. EMERY,
Committee of the Judges of Group XX.

FIG. 65.



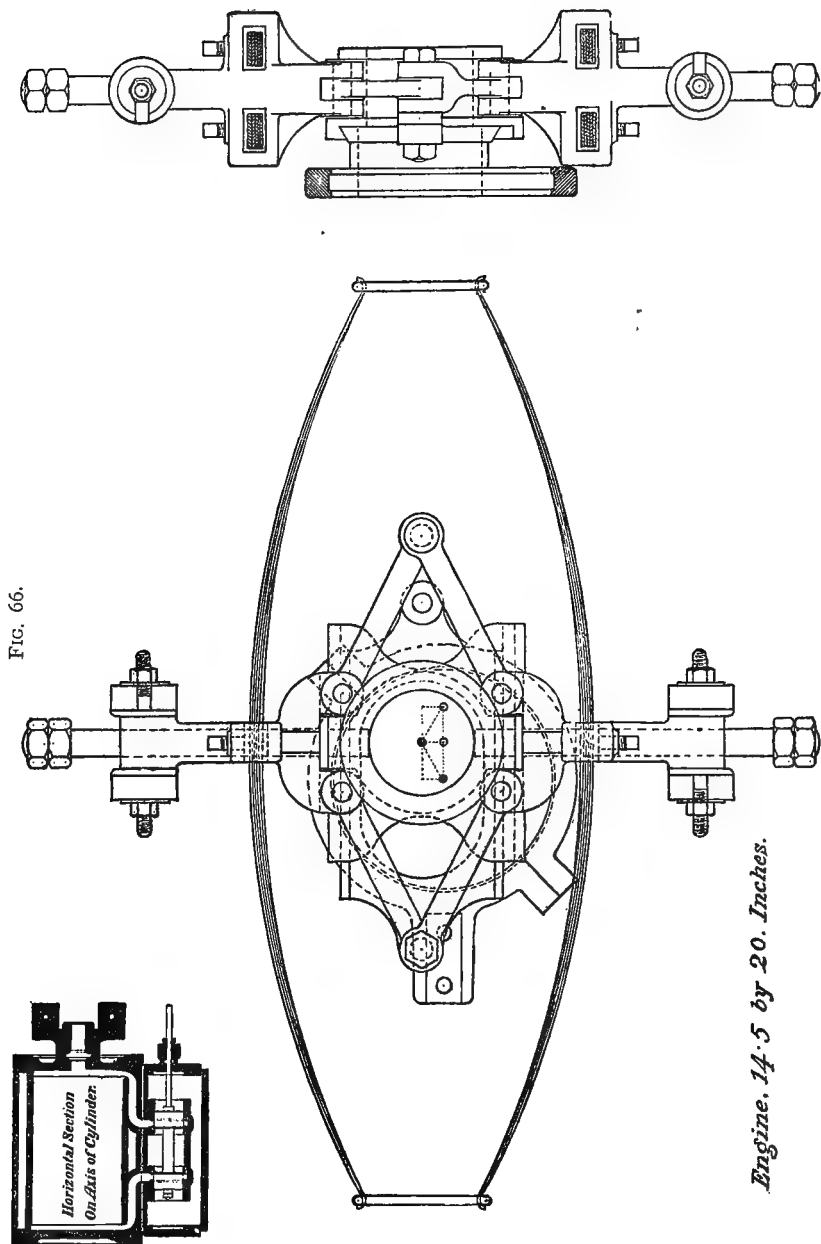
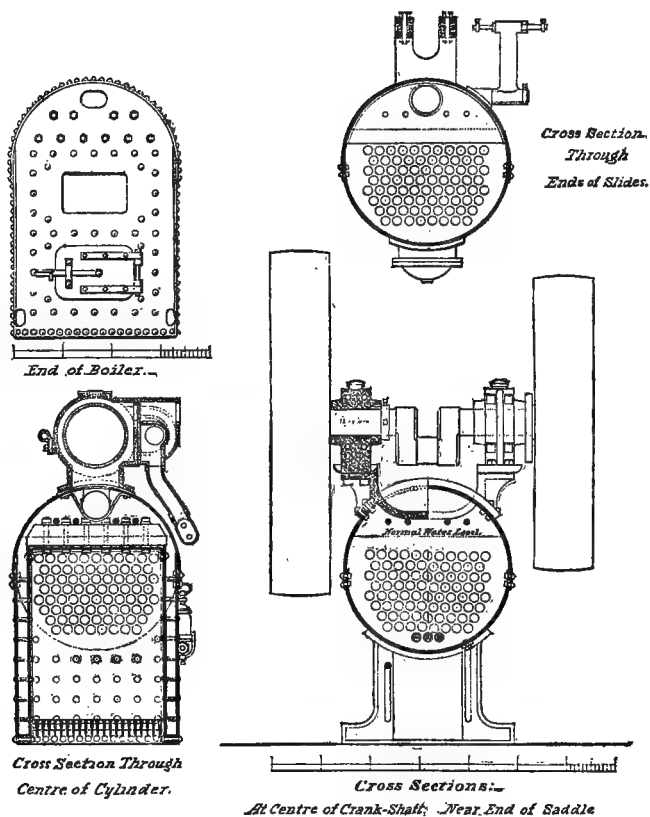


FIG. 66.

Engine, 14.5 by 20. Inches.

AUTOMATIC VALVE GEAR—J. C. HOADLEY COMPANY, LAWRENCE, MASS.

FIG. 67.

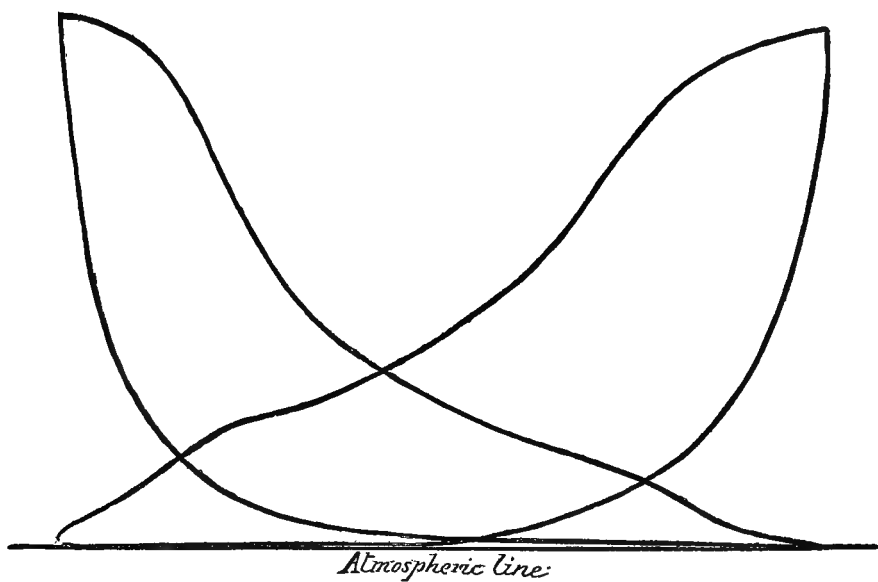


PORTABLE STEAM-ENGINE—J. C. HOADLEY COMPANY,
LAWRENCE, MASS.

FIG. 68.

Scale of Pressure

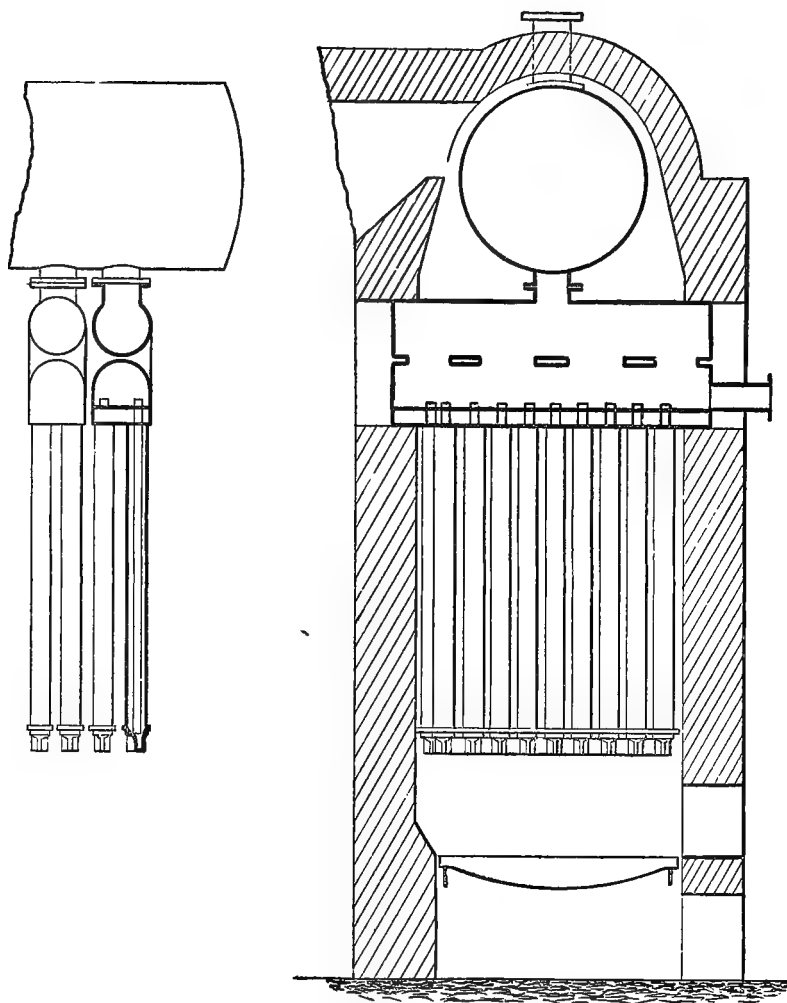
1 10 20 30 40 50 60 70 80 90 100



HOADLEY ENGINE—INDICATOR DIAGRAM.

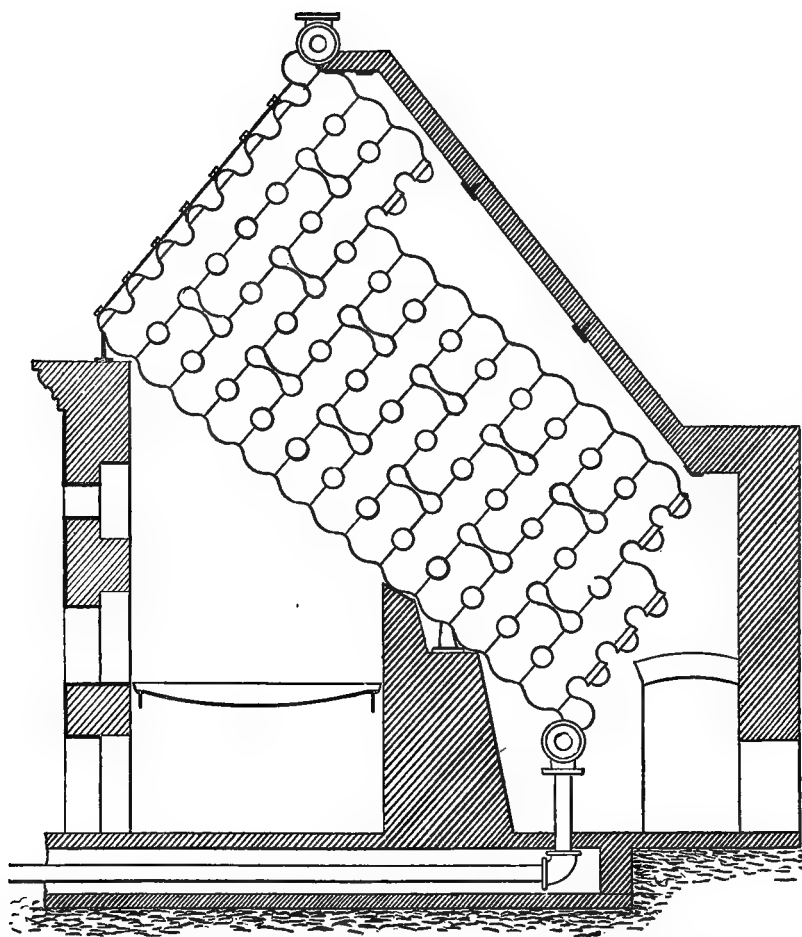
APPENDIX TO BOILER-REPORT.

EXHIBIT A.



WIEGAND SAFETY BOILER—STEAM GENERATOR MANUFACTURING COMPANY, PHILADELPHIA, PA.

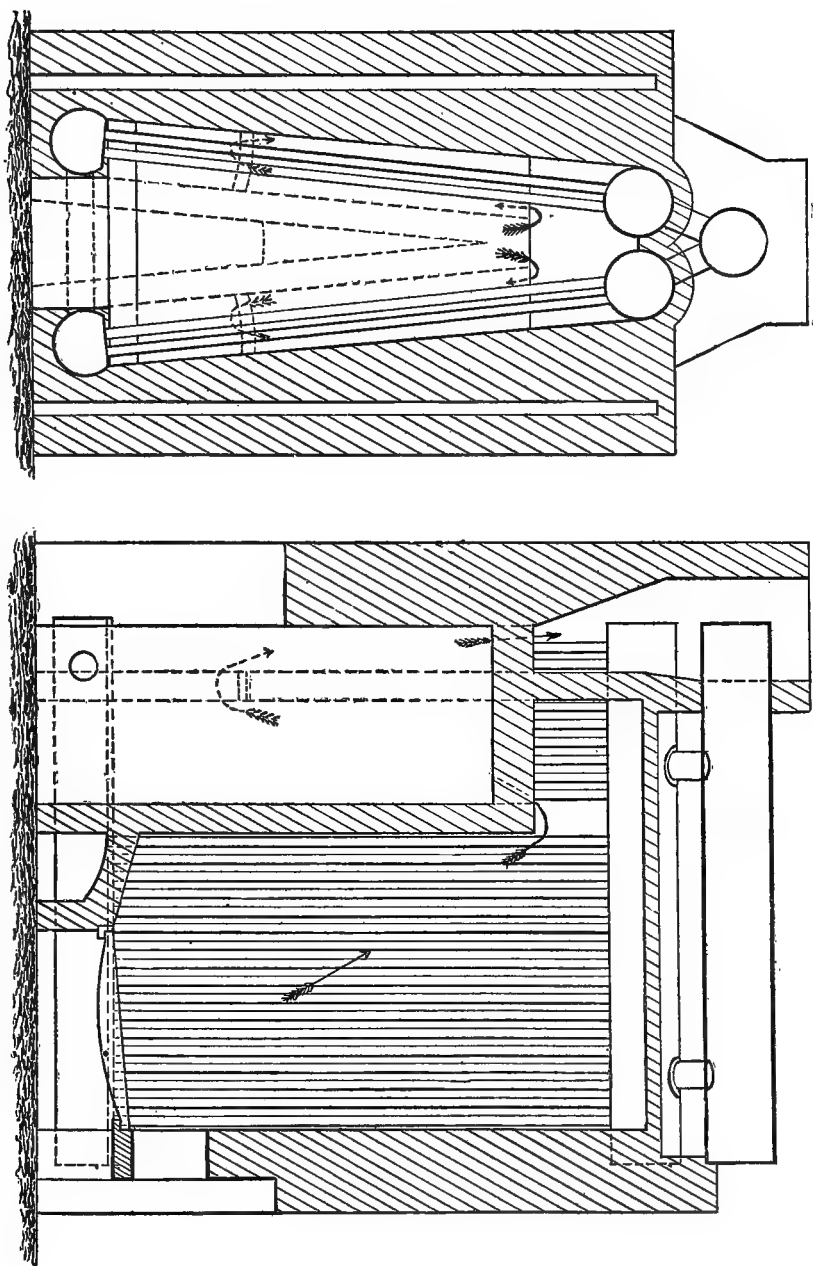
(For description, see § 36.)

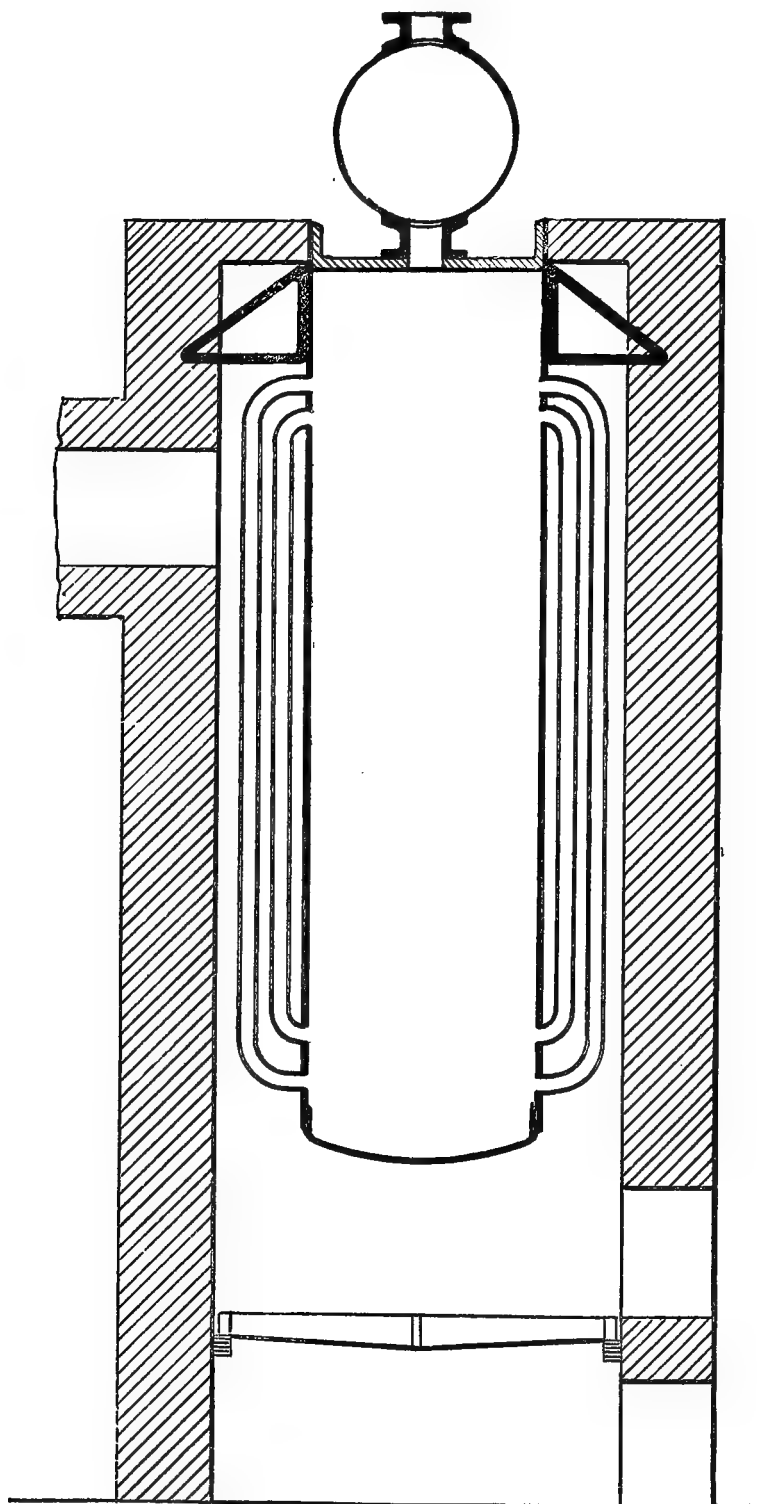


HARRISON SAFETY BOILER—HARRISON BOILER WORKS,
PHILADELPHIA, PA.

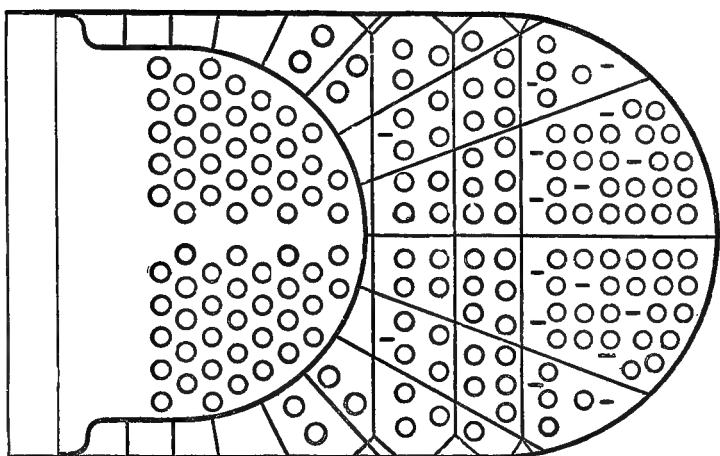
(For description, see § 37.)

FIRMENICH BOILER—J. & G. FIRMENICH, BUFFALO, N. Y.
(For description, see § 38.)



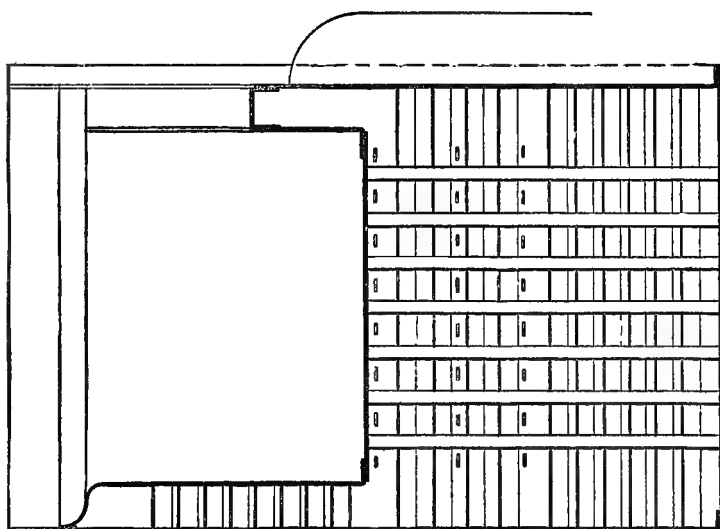


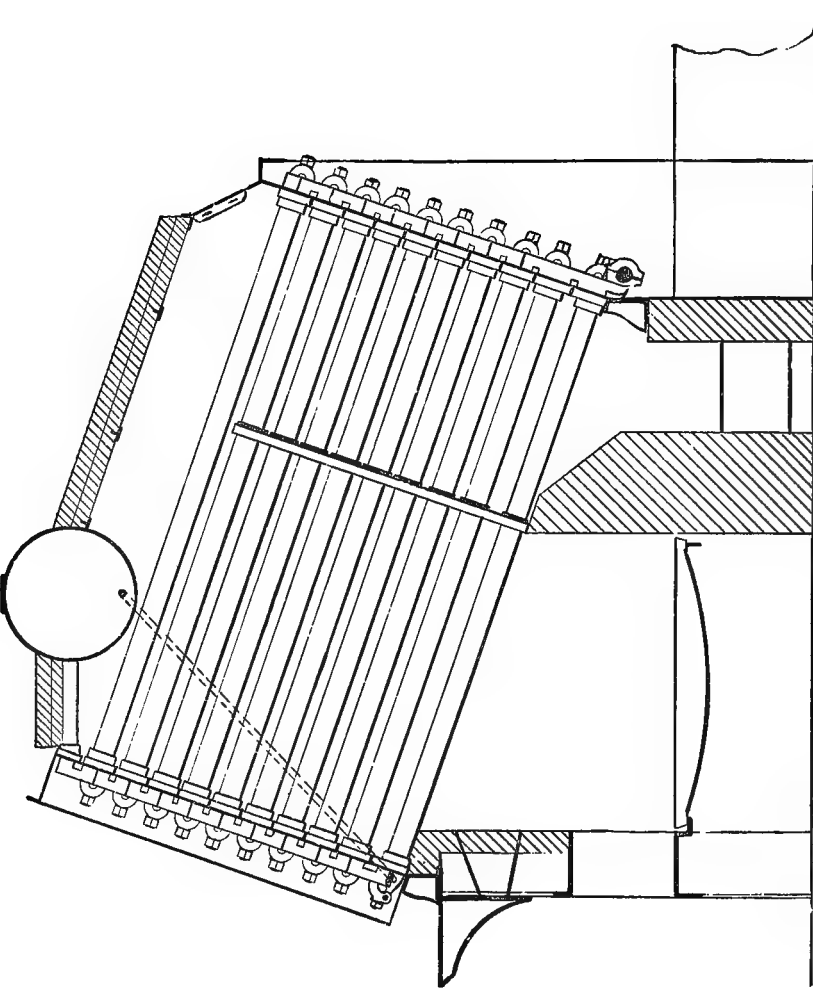
ROGERS & BLACK BOILER—CHAS. B. MILLER, PHILADELPHIA, PA.
(For description, see § 39.)



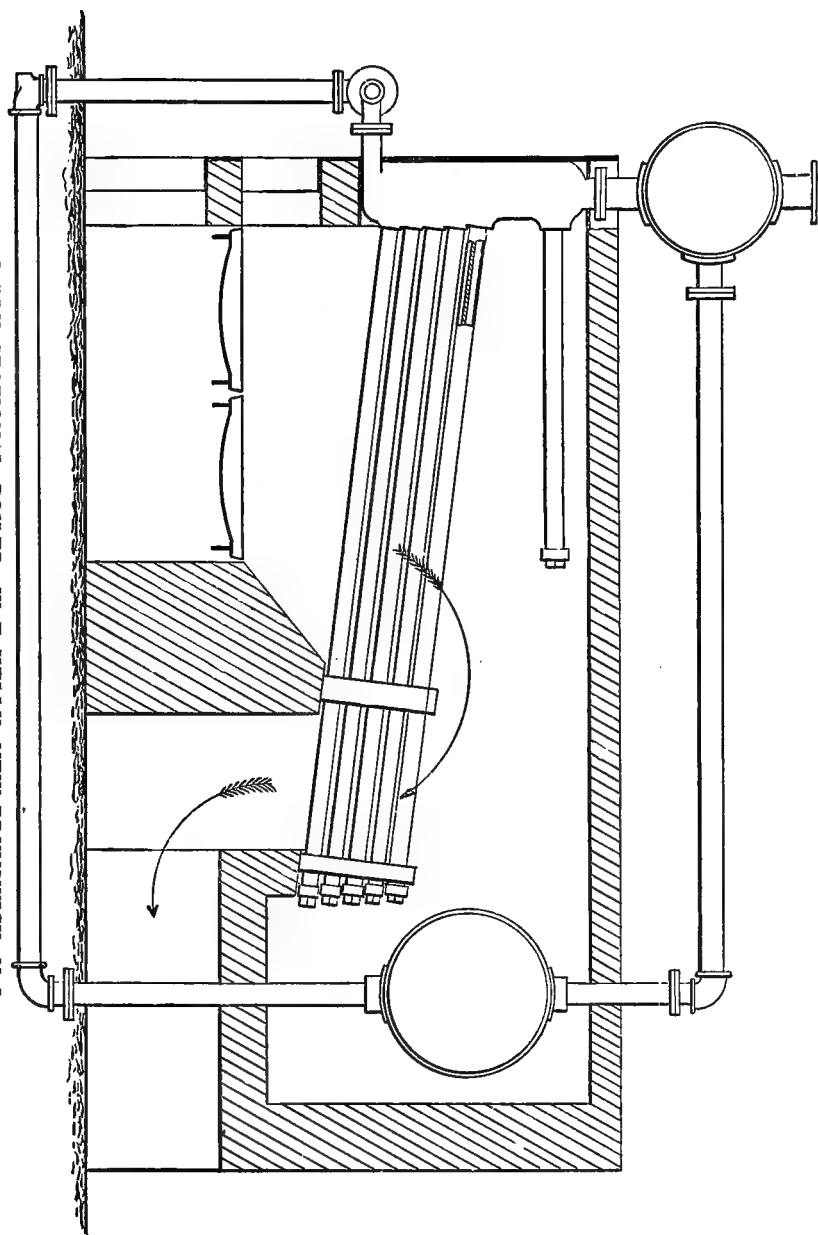
ANDREWS BOILER—W. D. ANDREWS & BRO., BROOKLYN, N. Y.

(For description, see § 40.)



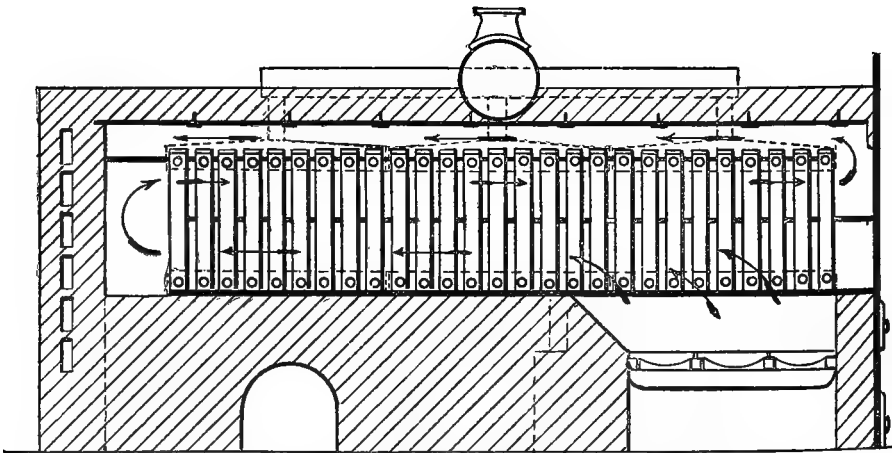
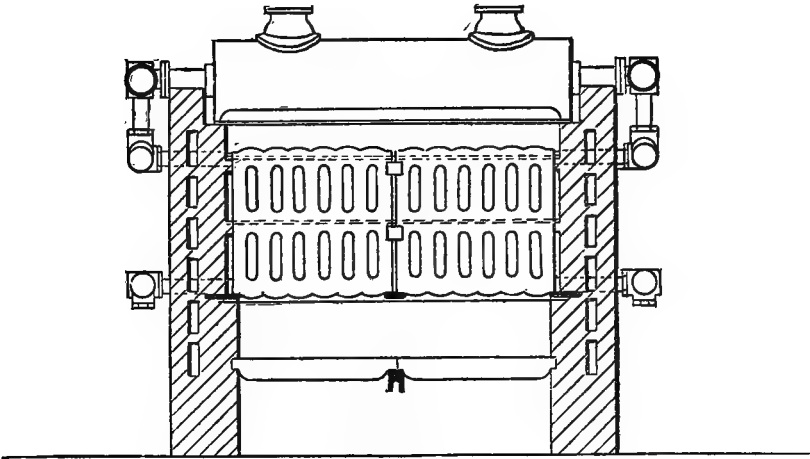


ROOT SAFETY BOILER.—ABENDROTH & ROOT MANUFACTURING CO., NEW YORK, N. Y.
(For description, see § 41.)

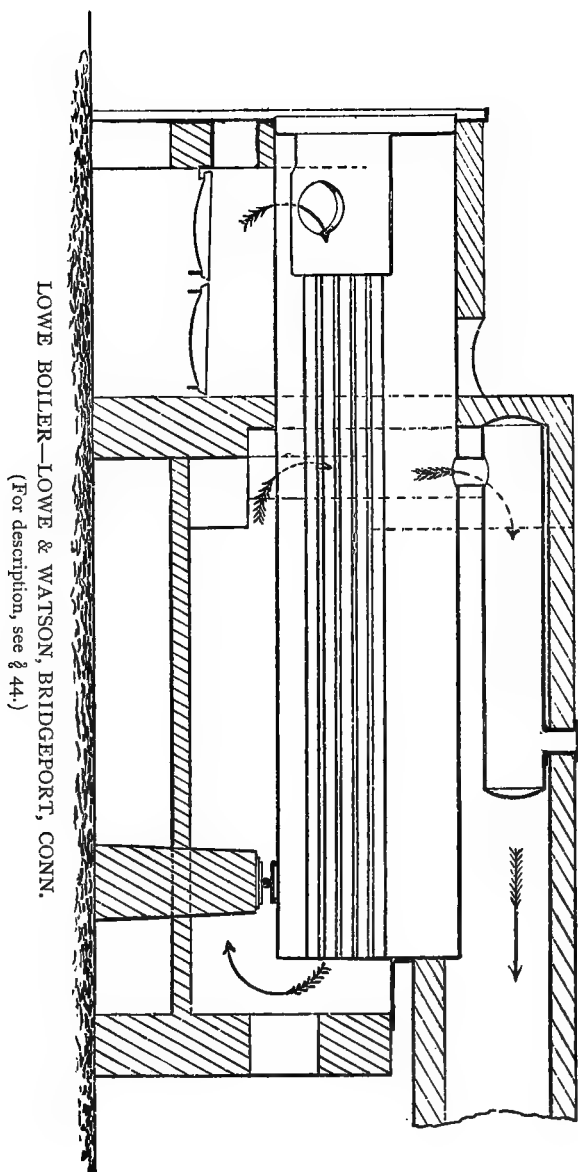


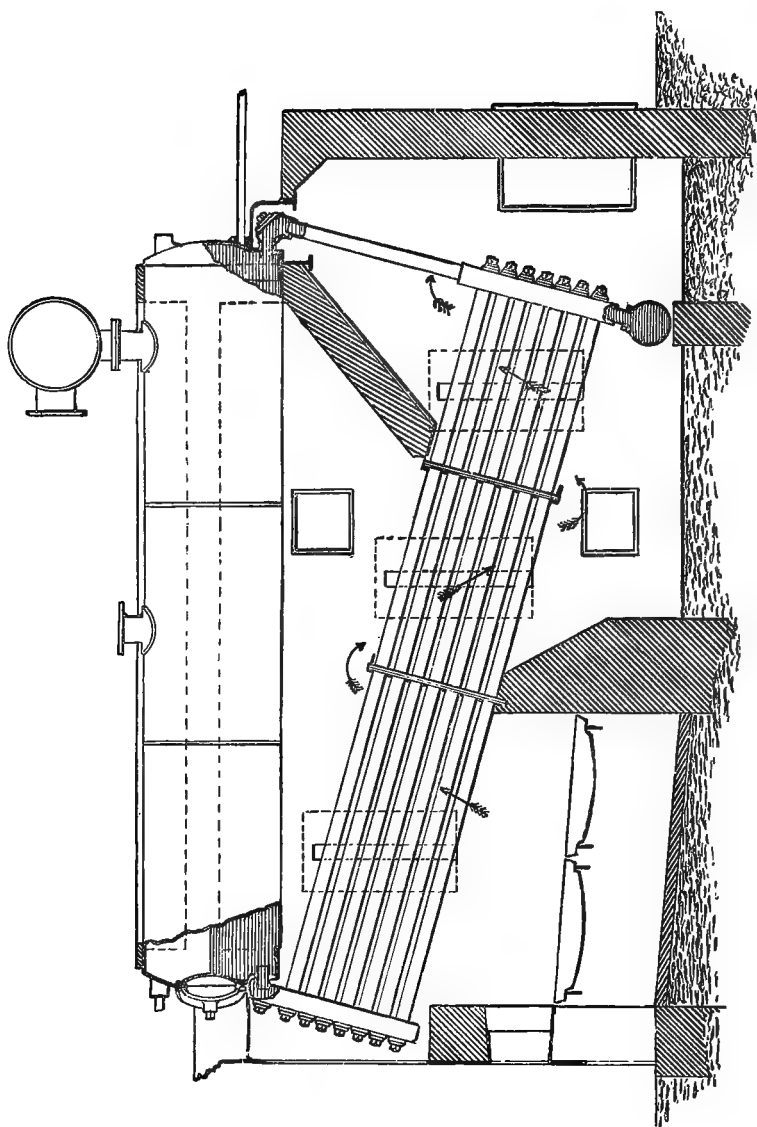
KELLY SECTIONAL BOILER—W. E. KELLY, NEW BRUNSWICK, N. J.

(For description, see § 42.)



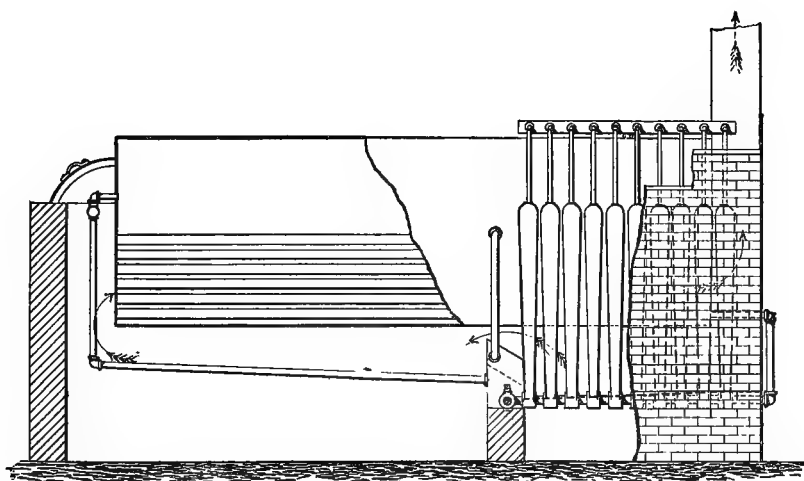
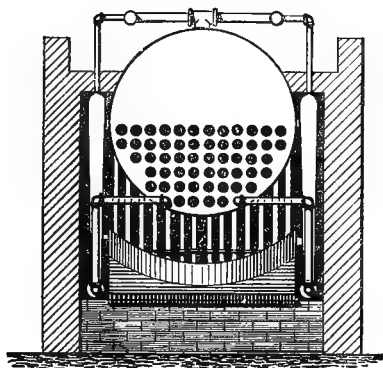
EXETER BOILER—EXETER MACHINE WORKS, EXETER, N. H.
(For description, see § 43.)



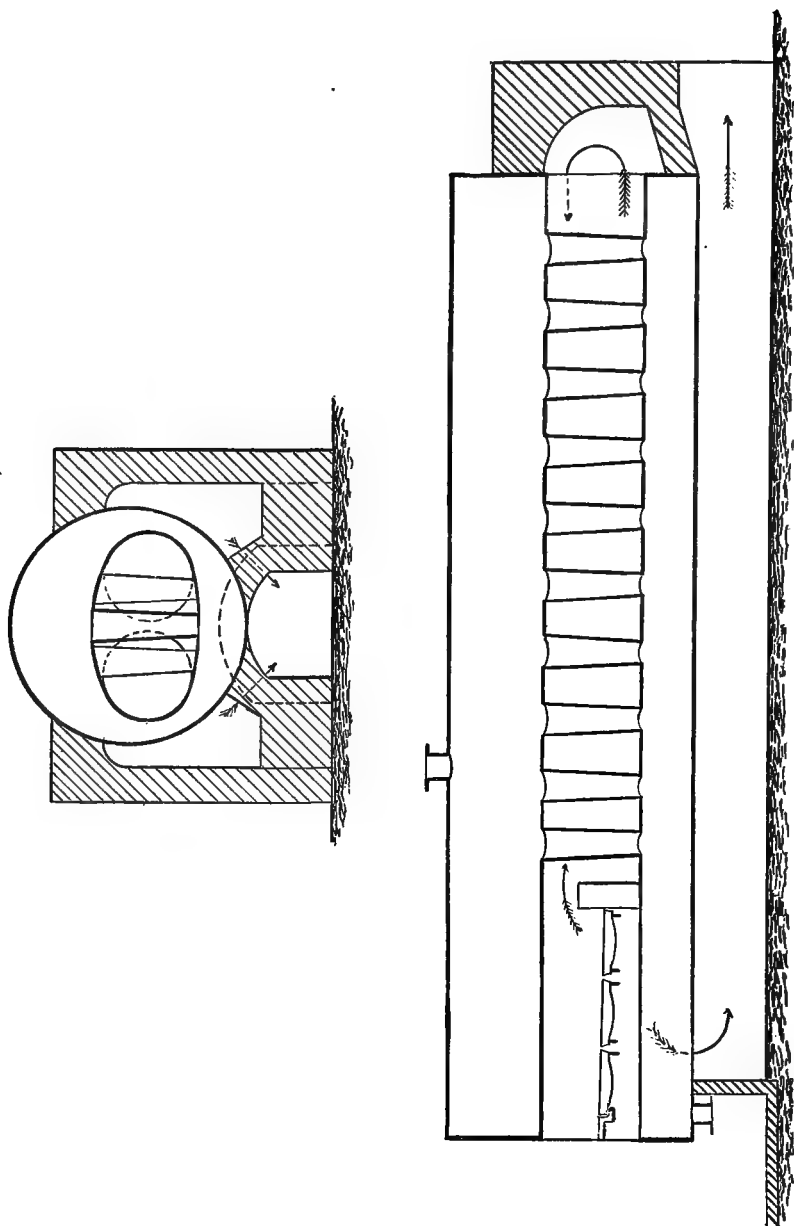


BABCOCK & WILCOX SECTIONAL BOILER—BABCOCK & WILCOX, NEW YORK, N. Y.

(For description, see § 45.)

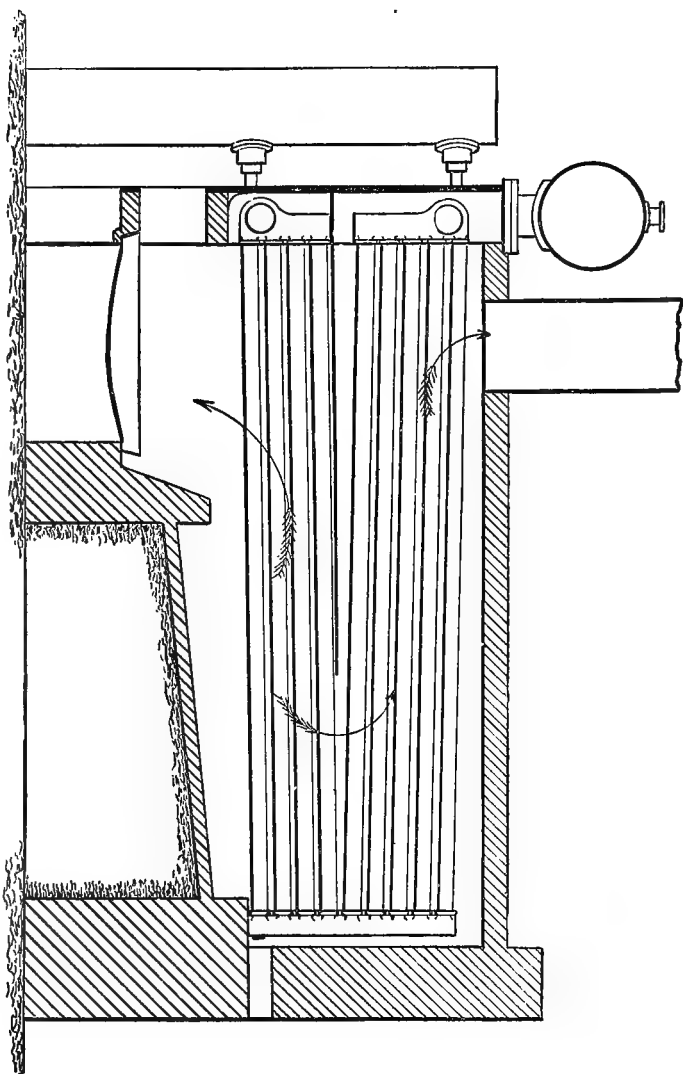


SMITH BOILER—CHAS. D. SMITH, BOSTON, MASS.
(For description, see § 46.)



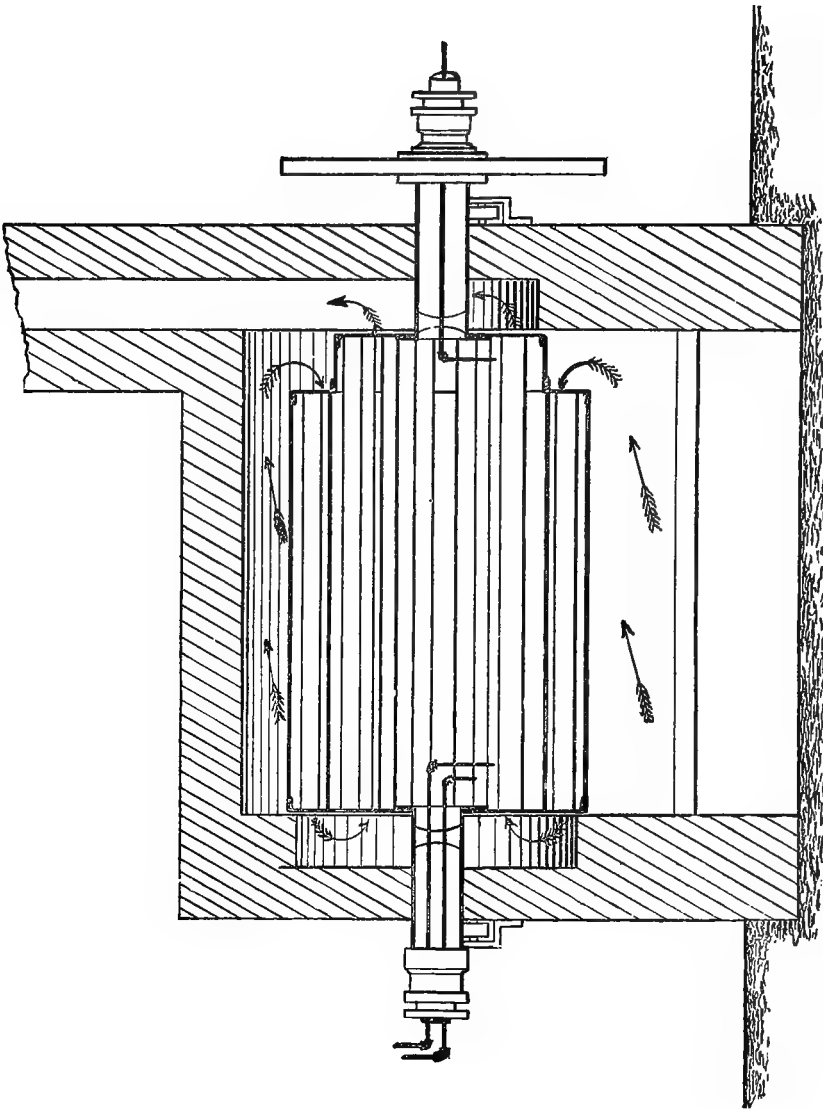
GALLOWAY BOILER—GALLOWAY & SONS, MANCHESTER, ENGLAND.

(For description, see § 47.)



ANDERSON SAFETY BOILER—P. P. MAST & CO., SPRINGFIELD, OHIO.

(For description, see § 48.)



PIERCE ROTARY BOILER—PIERCE ROTARY TUBULAR BOILER COMPANY, NEW YORK, N. Y.
(For description, see § 49.)

EXHIBIT B.

MEMORANDUM OF INSTRUCTIONS FROM THE JUDGES OF GROUP XX.,
IN RELATION TO THE TESTS OF STEAM-BOILERS.

The trials to commence on the day of September. Two trials, each of eight hours' duration, to be made of each boiler, one at maximum power, with natural draft, with fires kept clean, but not otherwise forced; the other with damper regulated to burn three-fourths as much coal as before, to approximate average working conditions.

During the trials the coal and feed-water used are to be weighed, and quality of steam furnished ascertained, by means of a calorimeter.

All experiments to be made with anthracite coal of the same kind, quality, size, and condition.

Coal to be weighed in an iron bucket, on a platform scale. Weights to be fixed so that all buckets will contain same quantity. The tally to be checked by weighing from a quantity previously measured, or by dumping the several buckets at beginning of hour in separate positions on the floor.

During the trials a steam pressure of seventy pounds is to be regularly maintained on boilers by adjusting the safety-valve, to permit steam to escape, or a throttle-valve, to admit the same to main steam-pipes in building.

Before beginning an experiment, steam is to be raised with dry wood and allowed to escape from the safety-valve, with stop-valve closed; and, when there is a sufficient quantity of ignited wood on grates, coal fires are to be established with weighed coal, and, after fires have reached proper thickness, coal is to be supplied regularly, as to quantity and intervals of firing.

At the end of each trial the fires are to be hauled out and extinguished, and the combustible and refuse carefully separated and weighed when dry. In commencing the experiment, the feed-pump is to be worked just fast enough to maintain the water level at a mark on water-gauge, and when the pressure commences to fall below 70 pounds, on account of starting the coal fire, the feed-pump is to be stopped, height in glass noted, and immediately after safety-valve closed. Near the end of the experiment the stop-valve is to be again closed and safety-valve adjusted to blow off at 70 pounds, and when the pressure commences to fall below 70 pounds, on account of hauling fires, the above operations are to be repeated. The water pumped into boiler to maintain the level during the above interval will be held to have been evaporated by the coal burned, subject to correction by the results obtained with calorimeter.

Feed-water, measuring apparatus, and calorimeter to consist of two tanks: one, the measuring and calorimeter tank, to be set on a scale on a platform higher than the other and be provided with a stirring apparatus and with a cock to drain water into the lower tank, which latter is to be connected to feed-pump. The upper tank to be supplied with a specific amount of water (from 400 to 500 lbs.) through a hose, which water is to be heated by steam from boiler admitted through another hose one (1) inch in diameter, connected through a valve with a $\frac{3}{4}$ -inch pipe placed inside the vertical outlet where steam finally leaves the boiler. Final weight with initial and final temperatures of water in measuring tank being noted, the water to be emptied into lower tank, and operation repeated. The temperature of water as fed to boiler to be determined from average in lower tank.

The steam pressures shown by an ordinary gauge to be recorded in logs, and a record of the pressure kept also by one or more approved recording gauges.

In addition to the above records, the temperature of external air, of fire-room, of the steam, and of the uptake to be noted; also reading of barometer and direction and approximate force of the wind. All records to be taken half-hourly, except in respect to calorimeter, which will be regulated by the demand for feed-water.

No boiler will be tested in a leaky condition or which has any connection which cannot be traced.

Drawings of the boilers tested are to be furnished by the exhibitors, sufficient in detail to enable the steam and water spaces, the heating surfaces, and draft area to be accurately ascertained.

Objections or suggestions as to the method of test or details of its management are to be submitted in writing for the action of the Judges, before the matter to be considered has been finally settled or concluded.

Trials to be made under the general direction of Messrs. Charles E. Emery, C. T. Porter, and Joseph Belknap, a committee of the Judges of Group XX. appointed for the purpose, and will be under the immediate direction of Mr. Hugentobler, who, with necessary assistants, will remain on duty throughout the entire duration of each trial.

A. T. GOSHORN, *Director-General*.

FRANCIS A. WALKER, *Chief of Bureau of Awards*.

EXHIBIT C.

LOGS OR RECORDS OF TRIALS.

The following are copies of the original logs or records of the experiments referred to in § 2 of the report made in the Bureau of Machinery under the direction of the Committee by Messrs. Hugentobler, Curtis, Pierce, Woods, and Hayward. Mr. Norton had charge of the preparation of the boilers for trials. All the gentlemen except the one first named were detailed at the time from the Bureau of Machinery. Messrs. Hugentobler, Newell, and Pemberton were engaged for a time afterwards in preparing the records so that they could be conveniently examined by the committee.

CHAS. E. EMERY,
CHAS. T. PORTER,
JOSEPH BELKNAP,

Committee of the Judges of Group XX. on Boiler Trials.

LOG OF CAPACITY TEST OF WIEGAND BOILER.

SEPTEMBER 16, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.46							7.5
10.31				1430	194	72	7
10.48	1430	177	72				2.5
10.57				1437	185.5	72	4.5
11.10	1432	187	72				5.5
11.25				1423	181.5	72	5
11.36	1399	130.5	72				5
11.50				1462.5	183	72.5	6
12.09	1315	185	73				3
12.20				1431.5	242.5	72.5	6
12.32	1401	173.5	74.5				3
12.51				1431.5	219.5	74	4
1.10	1376	236	75				5.5
1.20				1464.5	141	74.5	6
1.36	1409	182.5	73				5
1.52				1421	180.5	73	5
2.02	1412	186	72				5
2.20				1409	186.5	72	5
2.35	1410	191.5	72				9
2.57				1411	186.5	73	3
3.12	1409	173	72				4
3.30				1414	188	73	4
3.42	1406	191	73				6
3.59				1453	185.5	73	3
4.09	1406	188.5	72				5.5
4.25				1414	190	73	8
4.44	1406	194	73				5
4.55				1401	183	73	5
5.10	1406	192	73				8
5.26				1445	188.5	73	6
5.41	1414	182.5	84				6.5
5.46	600	233	93	1389	140	84	7.5

LOG OF CAPACITY TEST OF WIEGAND BOILER.

SEPTEMBER 16, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THEM.	PLY.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.46	70	.....	.....	312	.....	430	4397	367 Wood	744	455.5	30.12	7.5
10.15	70	74	.....	312	.....	560	1875.5	227	.....	.....	.....	7.5
10.45	70	75	.....	312	.....	600	.....	227	.....	.....	.....	4.5
11.15	69.25	72	90	310.5	.....	800	.....	234	.....	.....	.....	4
11.45	71	72	92	312	.....	675	.....	223	.....	.....	.....	5
12.15	70	72	94	312	.....	600	.....	230	.....	.....	.....	5.5
12.45	70	72	92	312	.....	550	.....	223	.....	.....	.....	4.5
1.15	70	72	92	312	.....	590	.....	227	.....	.....	.....	0
1.45	69.50	72	92	312	.....	592	.....	220	.....	.....	.....	3.5
2.15	69.50	72	91	311	.....	612	.....	230	.....	.....	.....	4
2.45	70	72	90	312	.....	570	.....	224	.....	.....	.....	5.5
3.15	76	73	91	315	.....	560	.....	204	.....	.....	.....	5
3.45	70	73	90	312	.....	620	.....	631	.....	.....	.....	5
4.15	70	70	90	312	.....	620	.....	423	.....	.....	.....	5
4.45	70	70	90	312	.....	620	.....	630	.....	.....	.....	5
5.15	70	71	90	312	.....	550	.....	688	.....	.....	.....	7.5
5.46	70	69	89	312	.....	555	.....	660	.....	.....	.....	7.5
.....	.....	.....	.....	.....	.....	.....	.....	759	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	296 Ret'd	.....	.....	.....	.....

LOG OF CAPACITY TEST OF WIEGAND BOILER.

SEPTEMBER 16, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
10.00	78	300	310	76	121.5	70 —70
10.20	"	"	307.5	74	110.5	70 —70
10.40	"	"	307.75	74	111.5	70 —70
11.00	"	"	308.875	76	118.5	70 —70
11.20	"	"	308	78	116	70 —70.25
11.40	"	"	306.75	77.5	114	69.75—70
12.00	"	"	309	75.5	118.5	70 —70.25
12.20	"	"	307.75	78.5	115	70 —70
12.40	"	"	308.50	77.5	119.5	70 —70
1.00	"	"	309	77.5	120	70 —70
1.20	"	"	308.50	78	118	70.25—70
1.40	"	"	308.875	76.5	119	70 —70
2.00	"	"	307	76.5	112.5	70 —70
2.20	"	"	308.50	76	116.5	70 —70
2.40	"	"	308.75	76.5	119	70 —70
3.00	"	"	309	75	117	70 —70
3.20	"	400	412.25	75.5	118	70 —69.5
3.40	"	"	411.75	77.5	119.5	70 —70
4.00	"	"	412.75	75.5	118.5	70.5 —69
4.20	"	"	413.25	74.5	118.5	70 —70
4.40	"	"	410.75	75.5	111.5	70 —70
5.00	"	"	411.25	79.5	117.5	70 —70
5.20	"	411.25	.....	.....	.....	.....
5.40	"	400	410.50	83	118	70 —69.5

LOG OF ECONOMY TEST OF WIEGAND BOILER.

SEPTEMBER 22, 1876.

No. 1.—RECORD OF FEED WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.53							5
10.30	1421	142.5	69.5				5
10.52				1422	119.75	70	3.5
11.07	1421	134	70				4
11.24				1421	152.5	70	3.5
11.38	1421	136.5	69.75				5
12.00				1421	147.5	70	3
12.15	1421	135.5	70				5
12.30				1472.5	144	70.25	4.5
12.45	1421	139	70				6.5
1.05				1430	132.25	74	3
1.17	1421	159.5	73				5
1.31				1430	155.50	71	5
1.40	1421	138.5	71				5
2.08				1463	132	71	5
2.21	1421	138	71				5
2.43				1421	144	71	5
2.55	1421	152	71				6
3.17				1421	155	70.75	5
3.35	1421	144.5	70.5				5
3.52				1421	142	70.50	5
4.10	1421	141.75	70.5				5
4.25				1421	129	71	4
4.41	1421	153	70.25				5
5.05				1421	122.50	70	5
5.25	1421	140	70.75				5
5.47				1421	142	71.5	5
5.53	1421	689.50	73.25				5

LOG OF ECONOMY TEST OF WIEGAND BOILER.

SEPTEMBER 22, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					Ther.	Pyr.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.53	69.5	69	78	311	.....	310	224	364.5	573.75	395	30.04	5
10.25	70	69	80	310	.....	522	235	Wood.	.....	.....	.....	5
10.55	70	69	80	313	.....	520	251.5	220	.....	.....	.....	2.5
11.25	70	70	81	315	.....	515	243.5	216	.....	.....	.....	4
11.55	70	70	82	313	.....	511	225	214	.....	.....	.....	2.5
12.25	71	72	86	313	.....	528	232.5	211	.....	.....	.....	2
12.55	70	72	84	312	.....	517	228	210	.....	.....	.....	0
1.25	70	70	87	312	.....	555	236	215.5	.....	.....	.....	4
1.55	70	70	86	312	.....	547	235.5	202	.....	.....	.....	4
2.25	69	70	88	312	.....	509	241	216	.....	.....	.....	5
2.55	70	69	90	313	.....	546	240	217	.....	.....	.....	7
3.25	70	69	90	313	.....	546	245	210	.....	.....	.....	5
3.55	70	69	90	314	.....	530	240	210	.....	.....	.....	4
4.25	70	68	90	314	.....	515	237.5	224	.....	.....	.....	4.5
4.55	70	68	86	313	.....	510	245	225	.....	.....	.....	5
5.25	71	68	88	315	.....	500	247	225	.....	.....	.....	5
5.53	70	68	88	319	.....	510	237	212	.....	.....	.....	5
.....	.....	.....	.....	.....	.....	.....	243.5	225	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	247.5	222	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	218	218	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	226	222	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	241.5	238	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	230	227	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	212	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	200	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	Ret'd.	.....	.....	.....	.....	.....

LOG OF ECONOMY TEST OF WIEGAND BOILER.

SEPTEMBER 22, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
10.10	79.875	400	412.75	74.50	117.50	70 —69
10.30	"	"	413.375	73.50	119.00	71 —70
10.50	"	"	414.25	72.50	121.50	70 —69
11.10	"	"	413.25	73.00	118.00	70 —71
11.30	"	"	415.00	73.50	123.50	70 —68
11.50	"	"	414.00	73.00	120.00	70.5—70
12.10	"	"	412.00	72.00	112.50	70 —69.5
12.30	"	"	413.25	72.50	118.50	70 —68.5
12.50	"	"	409.50	75.00	109.00	70 —68.5
1.10	"	"	409.625	76.00	110.00	70 —67
1.30	"	"	411.75	74.00	114.00	70.5—70
1.50	"	"	411.00	75.50	113.00	71 —70
2.10	"	"	412.00	74.00	114.50	69 —66
2.30	"	"	412.75	73.00	116.50	70 —67
2.50	"	"	411.50	74.50	114.00	70 —67.5
3.10	"	"	412.75	73.50	116.75	70 —69.5
3.30	"	"	413.25	74.00	119.00	70 —69
3.50	"	"	413.00	71.50	116.75	70 —70
4.10	"	"	412.25	73.50	116.00	70 —69.5
4.30	"	"	415.00	70	121.00	70 —69.5
4.50	"	"	412.75	73	117.50	70 —68
5.10	"	"	413.25	73	119.00	70 —70
5.30	"	"	412.125	74.50	116.00	70 —71
5.50	"	"	412.75	75	119.00	70.5—68

LOG OF CAPACITY TEST OF HARRISON BOILER.

SEPTEMBER 20, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.39							5
10.06	1430	131	70.5				5
10.20				1435.5	116.75	70.5	6
10.38	1431.5	134.5	71				5.5
10.55				1477.5	152	69.75	6
11.13	1396	145.5	71				5.5
11.30				1457	124.50	70	6
11.50	1378.5	178	69.75				9.5
12.15				1436	167.25	70.5	5.5
12.35	1372.5	209.5	70.50				5.5
1.01				1478.5	143.25	70.5	6.5
1.23	1384.5	142.75	73.75				6
1.50				1474.5	129.50	73	5
2.20	1413.5	172	73				5.5
2.51				1488.5	142.50	73	7.5
3.15	1402	152.75	72.25				7.5
3.45				1457.5	154.50	71.75	6
4.14	1425.5	148	71.75				5.75
4.40				1423	132.75	72	6.5
5.08	1404	139.50	71.50				7
5.35				1415.5	160.75	71	6.5
5.41	1394	1098.50	71				6

LOG OF CAPACITY TEST OF HARRISON BOILER.

SEPTEMBER 20, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.39	85	74	84	308	.....	342	231.5	226.5	307.5	277	29.79	6
10.10	70	74	84	305	.....	534	225	Wood	.....	.....	.....	4.5
10.40	70	76	88	296	.....	680	226	204	.....	.....	.....	5
11.10	70	76	90	305	.....	662	224	213	.....	.....	.....	4.25
11.40	70	77	92	313	.....	653	211	210	.....	.....	.....	7
12.10	70.5	77	92	309	.....	590	222	205	.....	.....	.....	6
12.40	70	80	92	314	.....	500	222.5	215	.....	.....	.....	6
1.10	70	80	90	310	.....	612	212.5	205	.....	.....	.....	6
1.40	70	80	92	310	.....	608	221	215.5	.....	.....	.....	5.5
2.10	70	80	92	310.5	.....	590	211.5	219	.....	.....	.....	6
2.40	70	80	92	309	.....	572	212	203.5	.....	.....	.....	5.5
3.10	70	80	93	309	.....	572	219.5	211.5	.....	.....	.....	6.5
3.40	70	81	94	310	.....	563	216	211	.....	.....	.....	6
4.10	69.75	80	92	308	.....	554	228	209.5	.....	.....	.....	5.5
4.40	70	76	92	310	.....	572	226	212	.....	.....	.....	6
5.10	70	74	94	310	.....	570	233	117.5	.....	.....	.....	6
5.40	70	.....	94	310	.....	500	221.5	225.5	.....	.....	.....	6
.....	.....	.....	.....	.....	.....	.....	234.5 Ret'd.	223	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	226.5	.....	.....	.....	.....

LOG OF CAPACITY TEST OF HARRISON BOILER.

SEPTEMBER 20, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
9.50	79.375	400.00	414.00	72.50	119.50	70 —70
10.15	"	"	412.75	74.50	117.50	70 —69
10.35	"	"	413.50	72.00	117	70 —68.5
10.55	"	"	413.50	72.50	117	70 —67
11.15	"	"	413.75	72.50	118	70 —66.5
11.35	"	"	412.75	72.50	116.75	70 —68
11.55	"	"	413.00	72.50	116.50	70 —66
12.15	"	"	413.00	72.00	116	70 —65
12.35	"	"	413.75	72.00	117	70 —69
12.55	"	"	413.25	72.00	117	70 —69.5
1.15	"	"	414.00	72.50	119.50	70 —71.5
1.35	"	"	413.875	74.00	119.50	71 —67
1.55	"	"	413.625	75.00	120.25	70 —66
2.15	"	"	413.50	73.50	117.50	70 —68.5
2.35	"	"	413.75	72.50	118.00	70 —67
2.55	"	"	413.25	73.00	117	70 —68
3.15	"	"	412.75	74.50	117.50	70 —66.5
3.35	"	"	413.00	73.00	117	69.5 —67.5
3.55	"	"	412.25	75.00	116	70 —67.5
4.15	"	"	412.25	74.50	116	70 —68
4.35	"	"	413.50	74.00	118.50	70.25—70
4.55	"	"	413.00	74.50	118.50	70 —68.5
5.15	"	"	413.25	73.50	117	70 —69.75
5.35	"	"	413.375	75.00	116.50	70 —68.5

LOG OF ECONOMY TEST OF HARRISON BOILER.

SEPTEMBER 21, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.10							5.625
9.40	1400.5	143	71.5				6.5
10.10				1479	160.5	71.5	7
10.33	1400.5	143.5	70.5				6
11.03				1476.5	122.5	72.5	8.5
11.35	1418.5	147.5	69.5				6.5
12.20				1491	112.5	70	4.5
12.55	1410.5	138.5	71				6.5
1.40				1490.5	148.75	72	6.5
2.12	1440	150.25	72				5
2.40				1498	148.25	70.5	7.5
3.10	1409	148.50	71				7
3.45				1454.5	146.75	70.5	6.5
4.15	1408.5	145.50	71				7.5
5.03				1472.5	219.5	72	5
5.10	1404	1135.0	72				5.625

LOG OF ECONOMY TEST OF HARRISON BOILER.

SEPTEMBER 21, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		Air.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.10	75	72	88	309	.....	392	238	177	170	194	30.30	5.625
9.40	71	72	88	309	.....	522	234	Wood	.....	.....	.....	6
10.10	70	78	86	312	.....	527	230	208	.....	.....	.....	7.5
10.40	69	78	88	309	.....	527	226.5	237	.....	.....	.....	4.5
11.10	70	78.5	90	307	.....	518	216	221	.....	.....	.....	5.75
11.40	70	79	89	313	.....	554	211	216	.....	.....	.....	6
12.10	70.5	78	92	311	.....	509	231	222	.....	.....	.....	8
12.40	70	78	92	311	.....	582	210.5	204	.....	.....	.....	4.5
1.10	70	78	92	311	.....	482	207	203	.....	.....	.....	10.75
1.40	70	77.5	92	310	.....	509	212	211.5	.....	.....	.....	6.5
2.10	70	77	94	312	.....	572	235	224	.....	.....	.....	5
2.40	70	77	94	313	.....	545	.....	211.5	.....	.....	.....	7.5
3.10	70	74	90	312	.....	490	72	216.5	.....	.....	.....	7.5
3.40	70	72	89	313	.....	491	Ret'd	.....	.....	.....	.....	7
4.10	70	72	90	312	.....	500	.....	.....	.....	.....	.....	6
4.40	70	70	86	312	.....	482	.....	.....	.....	.....	.....	9.5
5.10	65	70	91	307	.....	471	.....	.....	.....	.....	.....	5.625

LOG OF ECONOMY TEST OF HARRISON BOILER.

SEPTEMBER 21, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
9.30	79.75	400	412.25	72.50	114.75	70.5—69
9.45	"	"	412.75	71	114.25	70 —67
10.05	"	"	413.25	72	117.50	70 —67.5
10.25	"	"	413	72.50	116.75	70 —68
10.45	"	"	414.125	72.50	120	70 —68
11.05	"	"	414.25	73.50	120.50	70 —68.5
11.25	"	"	414.25	73.50	120.50	70 —66
11.45	"	"	414	71.25	118.25	70 —67
12.05	"	"	414.625	72	120.50	70 —66
12.25	"	"	412.50	70.50	120.50	70 —69.75
12.45	"	412.50	427	73.50	120	70 —68.5
1.05	"	400	415	77	123	70 —67
1.25	"	"	412.25	73.50	115.50	70 —66
1.45	"	"	413.625	73.50	119.00	70 —66
2.05	"	"	415	74.50	125.50	70.5—68.5
2.25	"	"	413.5	72	118	70 —68
2.45	"	"	414.5	72.50	120.50	70 —67.5
3.05	"	"	414	75	121.50	70 —68.5
3.25	"	"	413.25	73	117	70 —66
3.45	"	"	412.75	74	117	70 —63
4.05	"	"	412.50	74	117	70 —65
4.25	"	"	413	73.50	118.25	70 —68.5
4.45	"	"	412	74.50	117.25	70 —68
5.05	"	"	412.75	74.50	118.50	70 —67.5

LOG OF CAPACITY TEST OF FIRMENICH BOILER.

SEPTEMBER 25, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.50	.....	.....	.....	.....	.....	.....	6.5
10.30	.....	.....	.....	1456.5	170.25	70.5	6.5
11.06	1421	154.75	69.75	.....	.....	.....	5.5
11.37	.....	.....	.....	1421	172	68	6.5
12.08	1421	134.50	68.5	.....	.....	.....	7
12.40	.....	.....	.....	1421	156.25	68	7
1.15	1422.5	135.25	69.25	.....	.....	.....	7
1.53	.....	.....	.....	1421	153.50	70	7.5
2.30	1421	173.00	68.75	.....	.....	.....	7.5
3.16	.....	.....	.....	1455	132	69	6
3.47	1421	155	68.25	.....	.....	.....	7.5
4.22	.....	.....	.....	1423.5	170.5	68	7
5.14	1421	168	69	.....	.....	.....	8
5.50	.....	.....	.....	1421	792	68	6.5

LOG OF CAPACITY TEST OF FIRMENICH BOILER.

SEPTEMBER 25, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.50	72.5	74	86	.....	.....	.....	217	138	297.5	161	29.79	6.5
10.20	70	74	90	324	.....	.....	216	Wood.	.....	.....	.....	6.5
10.50	70	73	92	335	.....	.....	218	238	.....	.....	.....	7
11.20	70	73	91	343	.....	.....	224	220	.....	.....	.....	6
11.50	70	74	96	344	.....	.....	225	205	.....	.....	.....	7
12.20	70	76	98	354	.....	.....	220	203	.....	.....	.....	7
12.50	70	76	94	360	.....	.....	220	212	.....	.....	.....	8
1.20	70	76	94	360	.....	.....	222	227	.....	.....	.....	8.5
1.50	70	76	96	361.5	.....	.....	215	213	.....	.....	.....	8
2.20	70	76	94	368	.....	.....	219	228	.....	.....	.....	7
2.50	70	76	93	369	.....	.....	217	207	.....	.....	.....	7.5
3.20	70	76	94	377	.....	428	242	217	.....	.....	.....	6
3.50	70	75	94	375	.....	428	483 Ret'd.	62 Ret'd.	.....	.....	.....	8
4.20	70	74	94	366	.....	428	.....	.....	.....	.....	.....	8
4.50	70	74	93	366	.....	405	.....	.....	.....	.....	.....	8.5
5.20	70	74	90	365	.....	410	.....	.....	.....	.....	.....	8
5.50	70	73	86	359	.....	419	.....	.....	.....	.....	.....	6.5

LOG OF CAPACITY TEST OF FIRMENICH BOILER.

SEPTEMBER 25, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
10.05	79.625	400	413.75	71	116.75	70 —71
10.25	"	"	413.625	70	118	70 —68.5
10.45	"	"	413.25	71	116.50	70 —70
11.05	"	"	413.25	71.5	116	70 —69.75
11.25	"	"	413.50	71.5	117.50	70 —69
11.45	"	"	413.25	71	116.25	70 —65
12.05	"	"	413.50	71.5	117.50	70 —68.5
12.25	"	"	414.25	70.5	119.75	70.5—69
12.45	"	"	413.75	73	120.50	70 —68.5
1.05	"	"	414.00	71.5	118.50	70 —69
1.25	"	"	414.25	71	119	70 —68.5
1.45	"	"	413.50	72	118.50	70 —69
2.05	"	"	413.75	72	118.50	70 —68.5
2.25	"	"	413.75	71	118.50	70 —70
2.45	"	"	414.25	71	118.50	70 —68
3.05	"	"	414.75	71.25	120.50	70 —68
3.25	"	"	413.25	71.50	118	70 —70
3.45	"	"	414	71	119	70 —68
4.05	"	"	414.125	71.50	119	70 —67
4.25	"	"	413.75	71.50	118.75	70 —68.5
4.45	"	"	414.25	71.50	119.50	69.5—65.5
5.05	"	"	414.75	71.25	121.50	70 —68
5.25	"	"	413.50	73.25	120	70 —70
5.45	"	"	414	74.75	122	70 —69

LOG OF ECONOMY TEST OF FIRMENICH BOILER.

SEPTEMBER 26, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.40	.....	.....	.....	.....	.....	.....	6.5
10.05	1030	137.5	68.5	.....	.....	.....	6.5
10.36	.....	.....	.....	1421	140.25	68	6.5
11.15	1421	121.5	68.5	.....	.....	.....	6.5
11.49	.....	.....	.....	1421	168.50	68.5	6.5
12.25	1421	144.25	68.5	.....	.....	.....	6.5
1.05	.....	.....	.....	1421	139.50	68.5	6.5
1.40	1421	145.50	71	.....	.....	.....	6.5
2.15	.....	.....	.....	1421	155	70.5	8.5
3.35	1421	121.50	68.5	.....	.....	.....	8.5
4.35	.....	.....	.....	1421	175.50	69	10
5.40	1421	541.50	69	.....	.....	.....	6.5

LOG OF ECONOMY TEST OF FIRMENICH BOILER.

SEPTEMBER 26, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PVR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.40	70	72	80	347	.....	464	232	169	180.25	153.25	29.55	6.5
10.10	70	72	80	380	.....	455	222	Wood.	.....	.....	.....	5
10.40	70	70	82	380	.....	455	222	219	.....	.....	.....	8
11.10	70	70	86	371	.....	428	228	226	.....	.....	.....	5
11.40	70	68	84	373	.....	428	223	214	.....	.....	.....	6
12.10	70	68	83	376	.....	420	227	211	.....	.....	.....	6
12.40	70	69	85	371	.....	428	234	221	.....	.....	.....	6
1.10	70	70	86	363	.....	419	215	234	.....	.....	.....	6.5
1.40	70	70	82	362	.....	415	.....	240	.....	.....	.....	7.5
2.10	70	70	85	355	.....	401	.....	237	.....	.....	.....	8
2.40	70	70	86	347	.....	464	.....	207 Ret'd.	.....	.....	.....	9
3.10	70	70	86	331	.....	365	.....	.....	.....	.....	.....	9.5
3.40	70	70	84	329	.....	382	.....	.....	.....	.....	.....	9.5
4.10	70	70	86	339	.....	390	.....	.....	.....	.....	.....	7.75
4.40	71	68	84	343	.....	390	.....	.....	.....	.....	.....	9.50
5.10	70	68	82	346	.....	392	.....	.....	.....	.....	.....	8
5.40	70	66	80	342	.....	380	.....	.....	.....	.....	.....	6.50

LOG OF ECONOMY TEST OF FIRMENICH BOILER.

SEPTEMBER 26, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
9.55	79.75	400	412.50	74	117	70—69
10.15	"	"	412.75	71.25	115.50	70—69.5
10.35	"	"	412.50	71	114.25	70—67
10.55	"	"	413.50	71	117	70—69.5
11.15	"	"	413.75	71	118	70—70
11.35	"	"	414.50	71	121.25	70—68
11.55	"	"	412.25	71.25	114	70—68.5
12.15	"	"	411.75	71	111	70—69
12.35	"	"	412	76	118	70—67.5
12.55	"	"	411.25	79.75	117	70—68
1.15	"	"	409.50	82	117	70—70
1.35	"	"	415.75	72.50	126.50	70—68
1.55	"	"	414	70.25	118	70—67
2.15	"	"	413.75	71.50	118.50	70—69
2.35	"	"	413.50	70.50	117	70—67.5
2.55	"	"	415.25	70	121	70—68
3.15	"	"	415.25	69	121	70—67.5
3.35	"	"	414	70	118	70—68
3.55	"	"	415.25	69	121	70—69
4.15	"	"	415.25	70	122	70—70
4.35	"	"	418.50	71	135	70—68
4.55	"	"	413.75	71	118.75	70—68
5.15	"	"	413.50	72.5	119	70—69
5.35	"	"	413.50	73	119	70—68

LOG OF CAPACITY TEST OF ROGERS & BLACK BOILER.

SEPTEMBER 30, 1876.

No. 1.—RECORD OF FEED-WATER

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.20							11
10.04				1479	183.5	66.5	5.5
10.40	1415	177.5	65				2
11.17				1421	172.5	65	7
11.55	1423	123.5	65.5				9
12.40				1462.5	148.75	65.5	5.5
1.20	1421	137	65				7
2.03				1464	160.5	67.5	6.5
2.44	1422	156.5	66				3
3.21				1426	140.5	66	7.5
3.53	1420	141.5	65.5				7
4.42				1421	149	66	6.5
5.20	1421	214.5	66				8

LOG OF CAPACITY TEST OF ROGERS & BLACK BOILER.

SEPTEMBER 30, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.20	70	62	68	300	.....	400	224	161.5 Wood.	207.5	168	29.80	8
9.50	70	62	70	308	.....	613	233				"	3
10.20	70	66	74	309	.....	820	228	225			"	5
10.50	70	66	82	310	.....	700	224	206			"	11
11.20	70	67	80	309	.....	650	237	232			"	8
11.50	70	70	82	309	.....	610	221	210			"	2
12.20	69	70	82	308	.....	582	238	229			"	5
12.50	70	69	84	304	.....	615	237	214			"	11
1.20	70	70	82	304	.....	615	214	233			"	7
1.50	70.5	68	80	310	.....	630	212	210			"	7
2.20	70	68	78	309	.....	625	199.5	79			"	3
2.50	70	67	78	308	.....	680		218				4.5
3.20	70	68	80	309	.....	700		208				5
3.50	70	68	78	309	.....	650		199.5				7
4.20	70	67	80	309	.....	670		185.5 Ret'd.				8
4.50	70	62	79	309	.....	630						7
5.20	70	62	80	309	.....	600						8

LOG OF CAPACITY TEST OF ROGERS & BLACK BOILER.

SEPTEMBER 30, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM-PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
9.35	80.062	400	412.50	67	109.5	70 —66.5
9.55	"	"	412.25	66.25	107.75	70 —66
10.15	"	"	406.75	67	90	70 —68
10.35	"	"	410.75	66	103	70 —69
10.55	"	"	411.50	68	105	70 —67.5
11.15	"	"	413.75	67	114.50	70 —66.5
11.35	"	"	412.25	67	109.50	70 —67
11.55	"	"	412.25	67.50	109.25	70 —73.5
12.15	"	"	411.25	68	106.25	70 —66
12.35	"	"	411	68.75	110.50	70 —68
12.55	"	"	409.75	67.75	111	70 —67.5
1.15	"	"	412	67.50	113	70 —65
1.35	"	"	412.25	68.25	110	70 —66
1.55	"	"	413.75	69	115.50	70 —68
2.15	"	"	412.75	68	111.50	69.5—66
2.35	"	"	412	71.50	111.50	70 —67
2.55	"	"	411.50	69.50	110.25	70 —65
3.15	"	"	409.75	67.25	102.50	70 —71
3.35	"	"	415.50	68.50	121.50	70 —67
3.55	"	"	411	69.50	107	70 —70
4.15	"	"	411.50	68	108	70 —69
4.35	"	"	413	69.75	114.50	70 —72.5
4.55	"	"	409.75	68	102	70 —67
5.15	"	"	411.25	69	107	70 —68.5

LOG OF ECONOMY TEST OF ROGERS & BLACK BOILER.

SEPTEMBER 30 AND OCTOBER 1, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
5-33	.....	.....	.....	.....	.....	.....	8
6-30	.....	.....	.....	1502	149.5	66	9-75
7-15	1419.5	117.5	67	.....	.....	.....	6
8-04	.....	.....	.....	1508.5	118	66	7-50
8-56	1409.5	146	68	.....	.....	.....	3-50
9-55	.....	.....	.....	1490	169	67	5-50
10-55	1420.5	201	68	.....	.....	.....	8
A.M. Oct. 1.	.....	.....	.....	.....	.....	.....	.....
12-05	.....	.....	.....	1422	129.5	68	8
1-15	1415	171.5	68	.....	.....	.....	7
1-33	.....	.....	.....	1496	1004	67	8

LOG OF ECONOMY TEST OF ROGERS & BLACK BOILER.

SEPTEMBER 30 AND OCTOBER 1, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES, <i>Net.</i>		
					THEER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
5.33	77	61	78	314	.....	495	220	117	166	143	29.81	8
6.05	70	61	76	308	.....	620	217	Wood.	.....	.....	.....	6.75
6.35	68.5	60	76	308	.....	610	237	209	.....	.....	.....	7.5
7.05	70	61	76	310	.....	610	237	216	.....	.....	.....	3
7.35	70	66	76	310	.....	555	233	228	.....	.....	.....	1
8.05	70	66	77	310	.....	590	241	221	.....	.....	.....	6
8.35	70	66	76	310	.....	640	241	221	.....	.....	.....	10
9.05	70	65	74	310	.....	640	.....	221	.....	.....	.....	4
9.35	70	66	74	309	.....	540	.....	220	.....	.....	.....	6
10.05	71	66	74	310	.....	550	.....	82	.....	.....	.....	9
10.35	70	65	72	309	.....	563	.....	45 Ret'd.	.....	.....	.....	8.5
11.05	70	62	72	310	.....	530	.....	.....	.....	.....	.....	10
11.35	70	60	72	309	.....	540	.....	.....	.....	.....	.....	6
A.M.												
12.05	71	60	72	310	.....	530	.....	.....	.....	.....	.....	7.5
12.35	72	60	70	310	.....	545	.....	.....	.....	.....	.....	8
1.05	70	60	70	309	.....	545	.....	.....	.....	.....	.....	8
1.33	70	60	71	310	.....	540	.....	.....	.....	.....	.....	8

LOG OF ECONOMY TEST OF ROGERS & BLACK BOILER.

SEPTEMBER 30 AND OCTOBER 1, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM-PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
5.40	80.3125	400	411.25	69.5	107	70 —68
6.00	"	"	411.50	71	110	69.5—66
6.20	"	"	409.50	73	105	70 —67.5
6.40	"	"	413.75	74	120	70 —66
7.00	"	"	409.50	73	105.5	70 —65.5
7.20	"	"	411.25	71.75	110.5	70 —70
7.40	"	"	411.50	69	109.5	70 —68
8.00	"	"	409.875	73	107.25	70 —67.5
8.20	"	"	409.50	70	102	70 —66
8.40	"	"	412	72.50	112.50	65 —61
9.00	"	"	410.75	74	110	70 —68
9.20	"	"	412	70	110.50	70 —66
9.40	"	"	410.50	74	109.50	70 —70
10.00	"	"	407.75	73.5	98.75	70 —67
10.20	"	"	407.50	68	94.50	70 —67
10.40	"	"	409.75	71	104.50	70 —66.5
11.00	"	"	411	72.5	108.75	70 —67
11.20	"	"	409	69	99.50	69 —66
11.40	"	"	409.5	74	105	70.5—68
A.M.						
12.00	"	"	408.75	75	105	70 —67.5
12.20	"	"	408.75	73.5	103	70 —65.5
12.40	"	"	409.75	72.5	105	70 —67.5
1.00	"	"	409.25	74	104.5	70 —66
1.20	"	"	409.25	75	105	70 —66

LOG OF CAPACITY TEST OF ANDREWS BOILER.

OCTOBER 2, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
2.30							10
3.37	1404.5	121.5	64.5				4.5
4.25				1347	136.75	64.5	2
5.02	1422	120	64.5				5
5.40				1420	141.5	65	8
6.15	1438	149.5	65				7
7.15				1461.5	114	67	6.5
8.00	1421	189.5	68				5.5
9.00				1422	157.25	68	4.5
9.55	1421	118.5	68				1
10.25				1502.5	270.50	69	4
10.30	834	177	68.5				10

LOG OF CAPACITY TEST OF ANDREWS BOILER.

OCTOBER 2, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THRU.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
2.30	68	68	80	300.5	.....	320	237	146	309.5	173	29.80	10
3.00	70	68	84	313	.....	417.5	243	Wood.	.....	.....	.....	4.5
3.30	61.5	68	84	322	.....	400	234	220	.....	.....	.....	4
4.00	70	64	83	309	.....	370	229	220	.....	.....	.....	2.5
4.30	70	64	83	348	.....	400	220	220	.....	.....	.....	5
5.00	70	64	83	360	.....	470	228	229	.....	.....	.....	6.25
5.30	70	64	83	318	.....	370	229	205	.....	.....	.....	7
6.00	70	65	78	318	.....	390	233	218.5	.....	.....	.....	6.25
6.30	70	62	78	303	.....	370	238	221	.....	.....	.....	6
7.00	70	62	78	321	.....	365	.....	218	.....	.....	.....	9.50
7.30	70	64	78	318.5	.....	360	.....	221	.....	.....	.....	6.75
8.00	70	64	78	334	.....	370	.....	113.5	.....	.....	.....	5.50
8.30	67	62	76	329	.....	375	.....	.....	.....	.....	.....	5.50
9.00	70	62	76	338	.....	380	.....	.....	.....	.....	.....	4.50
9.30	70	62	75	334	.....	340	.....	.....	.....	.....	.....	2.75
10.00	70	63	76	339	.....	365	.....	.....	.....	.....	.....	3
10.30	70	63	76	333	.....	370	.....	.....	.....	.....	.....	10

LOG OF CAPACITY TEST OF ANDREWS BOILER.

OCTOBER 2, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
2.45	80.25	400	411.25	67	105.5	70 —61.5
3.05	"	"	411.75	67.25	109	70 —67
3.25	"	"	411.50	68	109	70 —61.5
3.45	"	"	411.5	69	109.5	70 —67.5
4.05	"	"	411	68.75	108	70 —67.5
4.25	"	"	409.75	68.75	104.5	70 —68
4.45	"	"	412	67	109.5	67.5—64
5.05	"	"	409.75	69	104	70 —66
5.25	"	"	410.25	69	105	70 —67.5
5.45	"	"	411.25	67	107	70 —68
6.05	"	"	409.75	70	104	70 —66
6.25	"	"	409.75	70	104	70 —68
6.45	"	"	411.25	70	108.5	70 —66
7.05	"	"	409.75	72.5	106	70 —66.5
7.25	"	"	409.75	72	106	70 —68
7.45	"	409.75	420.125	70	105.5	70 —67
8.05	"	400	409.75	71.75	105.5	70 —68
8.25	"	"	411	70	105.5	70 —67
8.45	"	"	409.50	72	105	70 —67.5
9.05	"	"	409.75	72	105	70 —65
9.25	"	"	414.50	67.5	118	70 —63.5
9.45	"	"	409.25	73	104	70 —63
10.05	"	"	410.75	72	108.75	70 —68.5
10.25	"	"	411	70	112.50	70 —67

LOG OF ECONOMY TEST OF ANDREWS BOILER.

OCTOBER 3, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.56	.....	.....	.....	.....	.....	.....	7.75
11.12	.....	.....	.....	1406.25	123.75	67.5	4.5
12.10	1423	133	65.5	.....	.....	.....	5.5
1.45	.....	.....	.....	1422	115.50	65	2.5
2.40	1423	124.75	65	.....	.....	.....	5
3.42	.....	.....	.....	1421	116.5	65	5.75
4.25	1421	116.5	65	.....	.....	.....	7.75
5.47	.....	.....	.....	1505	115.5	65.5	5
5.56	1436.5	1076.5	65	.....	.....	.....	7.75

LOG OF ECONOMY TEST OF ANDREWS BOILER.

OCTOBER 3, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES,

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WRIGHT OF ASHES. <i>Net.</i>		
					THÉR.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.56	72	62	79	344.5	.....	292	230	161	260.5	122.37	29.74	7.75
10.25	70	62	80	350	.....	363	233	Wood.	.....	.....	.....	5.5
10.55	70	62	83	342	.....	322	228	232	.....	.....	.....	4.5
11.25	70	66	83	325	.....	391	224	228	.....	.....	.....	3.25
11.55	70	67	82	323	.....	442	228	235	.....	.....	.....	5
12.25	70	69	83	311	.....	390	236	219	.....	.....	.....	4.75
12.55	70	69	83	319.5	.....	374	248	224	.....	.....	.....	6
1.25	70	70	84	316.5	.....	365	244 Ret'd.	244	.....	.....	.....	3.25
1.55	70	66	84	322	.....	372	.....	.....	.....	.....	.....	3
2.25	70	66	84	328	.....	482	.....	.....	.....	.....	.....	5.5
2.55	70	66	85	327.5	.....	460	.....	.....	.....	.....	.....	4
3.25	70	70	84	334	.....	465	.....	.....	.....	.....	.....	7
3.55	70	70	85	330	.....	502	.....	.....	.....	.....	.....	6
4.25	70	70	85	331	.....	458	.....	.....	.....	.....	.....	7.75
4.55	69	70	86	327	.....	460	.....	.....	.....	.....	.....	2
5.25	70	68	80	326	.....	437	.....	.....	.....	.....	.....	4
5.56	70	67	80	327	.....	430	.....	.....	.....	.....	.....	7.75

LOG OF ECONOMY TEST OF ANDREWS BOILER.

OCTOBER 3, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
10.10	80.75	400	410	65.5	101	69.5—64.5
10.30	"	"	413.25	66	112	70 —67
10.50	"	"	411.75	67	109	70 —67.5
11.10	"	"	412.75	67.5	109.5	70 —66.5
11.30	"	"	410.25	67.25	108	70 —67
11.50	"	"	412	67.25	110	70 —65
12.10	"	"	410.75	67.25	109	69 —67.5
12.30	"	"	411.25	68	107.5	70 —66.5
12.50	"	"	409.25	72	104.75	70 —67
1.10	"	"	408.75	71	101.5	70 —68.5
1.30	"	"	410.625	69.75	107.5	70 —66.5
1.50	"	"	410.25	66.75	103.25	70 —66.5
2.10	"	"	411.25	66.75	107	71 —66.5
2.30	"	"	410.75	66.50	105	70 —66
2.50	"	"	410.50	67	103.50	70 —67
3.10	"	"	412.25	67	110	70 —67
3.30	"	"	411.75	68.50	110	70 —67
3.50	"	"	411.25	68	108.25	70 —67.5
4.10	"	"	411.50	67	111	70 —67.5
4.30	"	"	412.75	66	111	70 —67
4.50	"	"	414.25	68	117.50	70 —67
5.10	"	"	411.375	66.5	106	70 —66.5
5.30	"	"	412.50	71	113.50	70 —67
5.50	"	"	411.50	72.5	111.75	70 —67

LOG OF CAPACITY TEST OF ROOT BOILER.

OCTOBER 5, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.59	.....	.....	.....	.....	.....	.....	8.25
10.35	.....	.....	.....	1406.5	192	64	3.50
10.47	1423	199	64.25	.....	.....	.....	5
10.55	.....	.....	.....	1421.5	128	63.75	7
11.14	1181.5	151	64	.....	.....	.....	6
11.27	.....	.....	.....	1445	149	63	9.5
11.48	1420.5	120	64	.....	.....	.....	7.5
12.06	.....	.....	.....	1417.5	122	64	6
12.20	1465	175.5	64.5	.....	.....	.....	7
12.40	.....	.....	.....	1416	155.75	63	8
1.00	1434	134	63.5	.....	.....	.....	12
1.15	.....	.....	.....	1419.5	121.5	65	8
1.38	1503.5	135	63.5	.....	.....	.....	3
1.51	.....	.....	.....	1422	140.75	63.5	6
2.10	1447	117.75	63.5	.....	.....	.....	3.5
2.27	.....	.....	.....	1418	134	64	4.5
2.46	1454	138.5	64.5	.....	.....	.....	8
3.06	.....	.....	.....	1428	147	63	7
3.27	1428	112	64	.....	.....	.....	5
3.45	.....	.....	.....	1424	143	63.5	7.5
4.05	1525.5	166.5	63.5	.....	.....	.....	5
4.23	.....	.....	.....	1421	144	63.5	5
4.45	1430	126	64	.....	.....	.....	5.5
5.03	.....	.....	.....	1421	134	63.5	5.5
5.25	1422	150	63	.....	.....	.....	6.5
5.45	.....	.....	.....	1420	126.5	63	6
5.55	1426.5	160.5	64	.....	.....	.....	7
5.59	.....	.....	.....	1162	724	63	8.25

LOG OF CAPACITY TEST OF ROOT BOILER.

OCTOBER 5, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.59	70	60	68	297	.....	.....	246	323	954	420.5	29.85	8.25
10.30	70	60	73	302	.....	.....	245	Wood.	.....	.....	.....	5
11.00	70	60	76	300	.....	.....	240	252.5	.....	.....	.....	5
11.30	70.5	60	78	311	.....	.....	244	247	.....	.....	.....	5
12.00	70	68	75	314	.....	.....	249	237	.....	.....	.....	5.5
12.30	70	70	70	316	.....	.....	252.5	236	.....	.....	.....	12
1.00	70	70	70	319	.....	.....	247	229	.....	.....	.....	12
1.30	70	70	70	313	.....	.....	237	242	.....	.....	.....	5.5
2.00	70.5	60	78	315	.....	.....	236	238	.....	.....	.....	5
2.30	70	60	75	316	.....	.....	238	220	.....	.....	.....	6.5
3.00	70	60	72	316	.....	.....	246	215	.....	.....	.....	2
3.30	70	60	70	326	.....	.....	229	220	.....	.....	.....	5.5
4.00	69	60	72	324	.....	.....	231	216	.....	.....	.....	5
4.30	70	60	72	335	.....	.....	233	205	.....	.....	.....	5.5
5.00	70	58	72	324	.....	.....	242	214	.....	.....	.....	5.5
5.30	70.5	58	72	329	.....	.....	238	216	.....	.....	.....	8
5.59	70	57	71	295	.....	.....	248	224	.....	.....	.....	8.25
.....	.....	.....	.....	.....	.....	.....	249	213	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	241	218	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	241	208	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	240	211	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	238	220	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	245	213	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	249	214	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	216.5	217	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	677 Ret'd.	203	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	157 Ret'd.	.....	.....	.....	.....

LOG OF CAPACITY TEST OF ROOT BOILER.

OCTOBER 5, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
10.15	79.75	400	412.75	64.5	108	70 —70
10.35	"	"	412	66.5	107	70 —69
10.55	"	"	413.25	64	109	70 —68
11.15	"	"	411	66	103.5	70 —70
11.35	"	"	412.50	66	109.5	70 —70
11.55	"	"	411.75	67.25	108	70 —69.5
12.15	"	"	411.125	65.50	108.25	70 —67
12.35	"	"	413.25	65	110.50	70 —67.5
12.55	"	"	412	68	109.50	70 —68.5
1.15	"	"	411.75	64.25	105.75	70 —68
1.35	"	"	412.25	66	109	70 —68
1.55	"	"	413	65.75	110.50	70 —68.5
2.15	"	"	411.25	68	107.75	70 —68.5
2.35	"	"	413	66	110.75	70 —69
2.55	"	"	412.25	66	108	70 —66.5
3.15	"	"	413.125	65.75	111.50	70 —68.5
3.35	"	"	412	67	110	70 —68
3.55	"	"	412.50	65.50	110.25	69.5—68
4.15	"	"	411.75	67	108.50	70 —67.5
4.35	"	"	412.50	66	110	70 —67
4.55	"	"	411.125	66	105.50	70 —67
5.15	"	"	411.75	65	106	68 —68
5.35	"	"	411.25	67.75	106.50	70 —69
5.55	"	"	410	73	106.75	70 —70

LOG OF ECONOMY TEST OF ROOT BOILER.

OCTOBER 6, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.54							8
10.25				1420.5	125	63	5.5
10.45	1445	140	63				8.5
11.12				1424.5	140.75	64	8
11.32	1444.5	137.5	65				4
11.50				1406.25	156.5	63	8.5
12.08	1422	178	65				5
12.37				1430	128.25	63.5	4.5
12.40	1421	164	64				9
1.03				1421.50	131.75	64	7
1.25	1421	126.5	63.5				6.5
1.40				1421.50	136.5	63	7
2.10	1415	131	63.5				6
2.34				1431	166.5	63.5	12
3.09	1436	156	64				6.5
3.30				1422.50	167	64	11.5
4.04	1421	124.5	64.5				5.5
4.30				1421.5	130	64	7.5
4.55	1421	135	64				11
5.23				1420	120.5	65	5
5.40	1421	126	63.5				4
5.52				1410	143.75	66	10
5.54	1378	1045	88				8

LOG OF ECONOMY TEST OF ROOT BOILER.

OCTOBER 6, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THHR.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.54	70	70	80	377	.....	Metal- lic ball.	206	331	499.5	320.2	29.48	8
10.25	70	72	80	305	.....		211	Wood.	.....	.....	.....	5.5
10.55	70	78	83	313	.....		209	217	.....	.....	.....	7
11.25	70	80	85	314	.....	398	222	201	.....	.....	.....	6
11.55	70	80	92	323	.....		224	225	.....	.....	.....	5.5
12.25	70	81	92	321	.....		221	225	.....	.....	.....	4.5
12.55	70	80	90	315	.....		220	217	.....	.....	.....	7
1.25	70	80	90	313	.....		219	210	.....	.....	.....	6.5
1.55	70	82	95	317	.....		227	219	.....	.....	.....	5
2.25	70	80	90	315	.....	367	219	215	.....	.....	.....	8
2.55	70	80	92	310	.....		229	213	.....	.....	.....	10
3.25	70	80	92	314	.....		230	219	.....	.....	.....	6.5
3.55	70	80	94	306	.....		230	223	.....	.....	.....	8.5
4.25	70	80	90	310	.....		237	215	.....	.....	.....	7
4.55	69	80	90	308	.....	415	230	221	.....	.....	.....	4
5.25	70	70	85	308	.....		230	226	.....	.....	.....	8
5.54	70	60	82	308	.....		223	222	.....	.....	.....
							148	212				
							210	59 Ret'd.				
							226 Ret'd.					

LOG OF ECONOMY TEST OF ROOT BOILER.

OCTOBER 6, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
10.10	79.75	400	413.125	64	110	70—70
10.30	"	"	412	66	108	70—69.5
10.50	"	"	412.375	65.5	109	70—70
11.10	"	"	410.75	72.5	109	70—65
11.30	"	"	413.125	64.5	110.5	68—70
11.50	"	"	416.25	66	122.5	70—69
12.10	"	"	414.50	66.5	117	70—69.5
12.30	"	"	416.50	65.5	122.5	70—66
12.50	"	"	415.625	67	121.5	70—68
1.10	"	"	417.375	68	127.25	70—67
1.30	"	"	416.375	68.5	124.50	70—68
1.50	"	"	414	68.5	117.25	70—68
2.10	"	"	414.875	71	123	70—68
2.30	"	"	414.25	66.5	116	70—69.5
2.50	"	"	415.75	66	120.50	70—68.5
3.10	"	"	414.75	68	118.50	70—68
3.30	"	"	413.50	70	117	70—68
3.50	"	"	417.375	67.25	126.50	70—68
4.10	"	"	417	68	125.50	70—68
4.30	"	"	413.75	71.50	118.75	70—67
4.50	"	"	416.25	66	121.25	70—67
5.10	"	"	418.50	69.25	131	70—71
5.30	"	"	415.75	74	126.5	70—67
5.50	"	"	416.375	74	129	70—68

LOG OF CAPACITY TEST OF KELLY BOILER.

OCTOBER 9, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
8.59							5.5
9.29	1031	134.5	60.5				5.5
9.45				1408	136.5	62.5	10
10.05	1421	146	60				5
10.23				1427.5	130.5	61.5	8.5
10.42	1421	132.5	60.5				7.5
11.03				1421	163	60.5	5.5
11.28	1445.5	127.5	60.5				4.5
11.45				1422	150	61	6.5
12.10	1500	142	62				11
12.35				1422	134	61	5.5
12.55	1455.5	144	61.5				9
1.20				1422.5	127	62	7
1.45	1426	130.5	63				6
2.04				1421	138.75	62	7
2.28	1421	138.5	62				10
2.45				1421	139.5	62	7
3.05	1513	126	62				8.5
3.25				1423	137.5	62	7
3.47	1442	129.75	62				5.5
4.10				1426	123.75	62.5	8
4.32	1442.5	135	62				8
4.52				1421	144.5	62	7
4.59	1437.5	1049	62				10.5

Deduct 70.3 pounds of feed-water for difference of level in boiler.

LOG OF CAPACITY TEST OF KELLY BOILER.

OCTOBER 9, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. Net.		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
8.59	70	.....	.....	305	.....	No means of getting pyrometer into flue.	224	185.5	240	312	30.08	5.5
9.30	70	52	82	306	.....		212.5	Wood.	.....	.....	.....	6
10.00	70	52	87	305	.....		224.5	224	.....	.....	.....	4.5
10.30	70	52	88	310	.....		215	212.5	.....	.....	.....	6.5
11.00	70	54	88.5	310	.....		222.5	224.5	.....	.....	.....	2
11.30	70	55	74	310	.....		216	215	.....	.....	.....	5
12.00	70	53	87	309.5	.....		214	219	.....	.....	.....	1
12.30	70	55	80	310	.....		221	222.25	.....	.....	.....	4.5
1.00	69	60	78	310	.....		223	226.5	.....	.....	.....	2.5
1.30	70	58	81	310	.....		226	223.5	.....	.....	.....	9.5
2.00	70	57	86	309	.....		222.5	220.5	.....	.....	.....	10
2.30	70	57	84	310	.....		219	225.5	.....	.....	.....	8
3.00	70	58	84	310	.....		227	219	.....	.....	.....	3.5
3.30	69.5	56	90	309.5	.....		222	225	.....	.....	.....	9
4.00	70	56	84	310	.....		220	217.5	.....	.....	.....	11
4.30	70	54	83	310.5	.....		213.25	217	.....	.....	.....	6.5
4.59	71	56	86	309	.....		222.5	214.5	.....	.....	.....	10.5
.....	.....	.....	.....	.....	.....	.....	226	213.25	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	217.25	217.25	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	224 Ret'd.	223.75	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	198.5 Ret'd.	.....	.....	.....	.....

LOG OF CAPACITY TEST OF KELLY BOILER.

OCTOBER 9, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
9.15	80.25	400	415.25	64	112	70—70
9.35	"	"	413	63.5	102.5	70—63
9.55	"	"	417.50	62.5	108	70—70
10.15	"	"	415.75	63.5	109.5	70—63.5
10.35	"	"	416.625	65.75	115	70—68
10.55	"	"	416.25	63	113.25	70—70
11.15	"	"	418	64.50	114.5	70—68
11.35	"	"	414.875	63.75	109	70—75
11.55	"	"	413.75	64.5	108.5	70—72.5
12.15	"	"	415.50	63.5	110	70—68
12.35	"	"	415.375	63.5	113	70—70
12.55	"	"	417.125	65	109	70—67
1.15	"	"	417.75	64	113	70—66.5
1.35	"	"	416	64.75	113.125	70—67.5
1.55	"	"	415	64.5	113.25	70—67
2.15	"	"	416.25	66.75	115.75	70—72.5
2.35	"	"	418.25	65	116.5	70—64
2.55	"	"	416.50	65	115	70—71
3.15	"	"	419.75	65.50	114.5	70—68
3.35	"	"	422.75	65.50	115	70—68
3.55	"	"	416	65	116.25	70—70
4.15	"	"	417.50	67	114.75	70—68
4.35	"	"	414.75	66.75	115	70—69
4.55	.....	.....	.....	.....	.....	.....

LOG OF ECONOMY TEST OF KELLY BOILER.

OCTOBER 9 AND 10, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
5.22							7
6.19	1442.5	136	63				0
6.40				1421.5	169.5	63.5	6
7.05	1447	131.5	68				6
7.28				1431.5	193.5	67	7
8.00	1445.5	316	67				5
8.25				1456	161.5	67.5	5
9.00	1519.5	135.5	67				5
9.40				1417	134	68	4.5
10.11	1501	162	69				5
10.36				1453	219	68	10
11.21	1521	128.5	68				3
11.48				1421	196	66	5
A.M.							
12.15	1488.5	205	66.5				4
12.42				1421	151	67.5	3
1.15	1500	133	67.25				6
1.22				1451	721	68	11

Deduct 56.25 pounds of feed-water for difference of level in boiler.

LOG OF ECONOMY TEST OF KELLY BOILER.

OCTOBER 9 AND 10, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21	
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.	
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>			
					THER.	PYR.							
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.	
5.22	76	54	80	312	.....	No means of getting pyrometer into flue.	224	185.5	238	214.5	29.97	7
5.50	70	.....	84	310	.....		206.75	Wood.	.....	.....	.....	3.5
6.20	70	.....	82	309.5	.....		213	221	.....	.....	.....	3
6.50	70	.....	90	310	.....		218	218	.....	.....	.....	5.5
7.23	70	48	80	309.5	.....		225	212.5	.....	.....	.....	5.5
7.50	70	.....	80	310	.....		220	199.75	.....	.....	.....	3
8.20	70	.....	76	309	.....		219	222	.....	.....	.....	6.5
8.50	70	.....	86	310	.....		216.5	226.5	.....	.....	.....	5
9.20	70	46	86	309	.....		215.5	213	.....	.....	.....	4.5
9.50	70	.....	86	310.5	.....		217	221.5	.....	.....	.....	2
10.20	70	46	85	309	.....		227	214	.....	.....	.....	4
10.50	70	.....	84	311	.....		223.5	220	.....	.....	.....	7.5
11.20	62	.....	84	310	.....		224	212	.....	.....	.....	3
11.50	70	.....	87	310.5	.....		.....	212	.....	.....	.....	1
A.M.													
12.20	71	45	88	311	249	3.5
12.50	70	88	310	296.5 Ret'd.	4.5
1.22	70	44	86	309	11

LOG OF ECONOMY TEST OF KELLY BOILER.

OCTOBER 9 AND 10, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
5.35	80.5	400	412.5	73.5	106.125	70 —66
5.55	"	"	413.375	68.25	110.50	70 —67
6.15	"	"	411.375	72.50	111	70 —68.5
6.35	"	"	417.25	66	122	70 —68
6.55	"	"	415.125	67.5	114.25	70 —64
7.15	"	"	416	74.5	122.25	70 —66
7.35	"	"	411.75	74.5	113.75	69 —70
7.55	"	"	413.25	72.5	115.25	70 —65
8.15	"	"	413.25	71	112.75	70 —62
8.35	"	"	414.25	71.25	122.25	70 —69
8.55	"	"	412	75	114.50	70 —67
9.15	"	"	415.25	70	121	70 —67
9.35	"	"	411	79	115.50	70 —69
9.55	"	"	412	68.5	113	70 —68
10.15	"	"	413.25	71	115.50	70 —66
10.35	"	"	415.25	72.5	116.50	70 —64
10.55	"	"	414	69	116	70 —75
11.15	"	"	413.50	70.25	115.25	70 —62
11.35	"	"	414.75	72.50	120	70 —70
11.55	"	"	413.75	70	114.50	70.5—64
A.M.						
12.15	"	"	412.75	70.50	113	70 —66
12.35	"	"	411.25	73	110.25	69.5—64.5
12.55	"	"	412.50	74	115	70 —67.5
1.15	"	"	411.75	73.25	114	70 —71

LOG OF CAPACITY TEST OF EXETER BOILER.

OCTOBER 12, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.32							10 —8
10.17	1403	157	66				5.5—7
10.37				1433	117.5	62	6 —3.5
10.53	1474	135	60				6 —9.5
11.30				1404	129.25	59.5	3 —1
11.46	1531	169.5	59				1.5—1
12.05				1414	119	59	7.5—9
12.30	1513.5	128.75	60				5 —6
12.57				1407.5	131.75	59.5	1.5—2
1.20	1504	154.5	59				1 —4
1.38				1409.5	183	60	6.5—9
2.01	1502	157.25	59				8.5—9
2.25				1418.5	162	60	8.5—8.5
2.56	1504	134.5	61				6 —5
3.14				1426	151.25	60	8.5—7.5
3.40	1509	139.75	61				6.5—8
4.00				1420	146	61	6 —9
4.34	1506	127.75	62				1.5—8
4.58				1435	159.75	60	5 —2
5.17	1504	158.50	62				6.5—3.5
5.32	1505	1458.75	62	1440	163.50	60	10 —8

LOG OF CAPACITY TEST OF EXETER BOILER.

OCTOBER 12, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. Net.		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.32	70	49	88	310	.....	375	230.5	170	578	304.5	30 20	10 —8
10.00	70	51	82	299	.....	401	229.5	Wood.	.....	.....	.....	7 —11
10.30	70	57	83	308	.....	446	229.5	235.5	.....	.....	.....	3 —1
11.00	70	.....	80	309	.....	446	229.5	229	.....	.....	.....	0.5—6
11.30	70	55	80	299	.....	432	223.5	221.5	.....	.....	.....	10 —4
12.00	70	.....	80	298	.....	444	231	227	.....	.....	.....	8 —7
12.30	70	67	83	298	.....	437	231	227	.....	.....	.....	5 —6
1.00	70	.....	84	307	.....	464	227	234.5	.....	.....	.....	3 —2.5
1.30	70	69	82	308	.....	455	233	235	.....	.....	.....	8 —9
2.00	70	.....	81	308	.....	446	233	227.5	.....	.....	.....	8.5—8.5
2.30	70	57	84	308	.....	437	238.5	227	.....	.....	.....	9 —9
3.00	70	57	84	309	.....	464	243	235.5	.....	.....	.....	3 —4.5
3.30	70	58	84	309	.....	464	240	238	.....	.....	.....	5 —7
4.00	70	60	85	307	.....	460	238.5	240	.....	.....	.....	4 —8
4.30	70	59	84	309	.....	454	235.5	236.5	.....	.....	.....	7.5—8
5.00	70	58	84	308	.....	437	229	216	.....	.....	.....	7 —7
5.32	70	54	78	308	.....	446	217	220	.....	.....	.....	10 —8
.....	.....	.....	.....	.....	.....	.....	.....	266.5	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	217	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	133 Ret'd.	.....	.....	.....	.....

LOG OF CAPACITY TEST OF EXETER BOILER.

OCTOBER 12, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
9.55	79.75	400	414	62	111	70—67
10.15	"	"	414.25	72	120	69—66
10.35	"	"	427.25	62.25	113.25	70—65
10.55	"	"	415.50	62	115	70—72.5
11.15	"	"	414	62	109.75	70—67.5
11.35	"	"	427.125	61.5	104.50	70—68
11.55	"	"	416	61.75	112.25	70—69
12.15	"	"	429.50	65	120.25	70—71.5
12.35	"	"	414.25	62.50	110.75	70—68
12.55	"	"	419	63	110.50	70—62
1.15	"	"	413.25	63.25	109	70—70
1.35	"	"	414.50	62.75	111.75	70—65
1.55	"	"	415	61	111.50	68—62
2.15	"	"	425.75	65.50	113.50	70—69.5
2.35	"	"	415.50	63	116	70—70
2.55	"	"	423.50	67	111.75	70—69.5
3.15	"	"	415	64	114.75	70—73
3.35	"	"	412.25	64	116.50	70—70
3.55	"	"	415.25	71	108.25	70—70
4.15	"	"	414.50	63.5	112.50	70—68
4.35	"	"	414	63	115.50	70—68.5
4.55	"	"	423.25	63.25	115.75	70—69
5.15	"	"	429	63	117.5	70—64
5.25	"	"	419.25	64.5	117	70—68

LOG OF ECONOMY TEST OF EXETER BOILER.

OCTOBER 12 AND 13, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
5.47							9 —6
6.15	1458.75	141.5	64.5				7 —7
6.39				1421	126	64.5	5 —6.5
7.18	1431.5	155.25	66				10.5 —8
7.55				1422	132.75	68	2 —2
8.21	1425	162	68.5				10.5 —2.5
9.00				1420.5	150	69.5	8.5 —5
9.44	1420	146.5	69.5				10.5 —7
10.16				1420.5	141.25	70	10 —2
10.59	1432.5	141.25	71				7.25—3
11.30				1421	134.75	70.5	10.5 —8
12.11	1454.5	139.5	70.5				4 —4
12.50				1420	139.25	70	4 —8
1.23	1430	135.75	70				8 —6
1.47				1420	260.25	66	10.5 —10.5

Deduct 325 pounds of feed-water for difference of level in boiler.

LOG OF ECONOMY TEST OF EXETER BOILER.

OCTOBER 12 AND 13, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
5.47	70	51	88	310	.....	446	215	210.5	300	256	30.15	9 —6
6.15	70	49	88	308	.....	464	223	Wood.	.....	.....	.....	8 —9
6.45	70	48	84	308	.....	437	231	190	.....	.....	.....	8 —3
7.15	70	47	87	309	.....	437	231	193	.....	.....	.....	9 —5
7.45	70	48	88	308	.....	428	228	190	.....	.....	.....	2 —9
8.15	70	44	90	308	.....	428	226	214	.....	.....	.....	5 —10
8.45	70	44	80	307	.....	428	224	219	.....	.....	.....	11 —5
9.15	.....	.....	.....	.....	.....	.....	217	210	.....	.....	.....	8 —1
9.45	70	44	82	307	.....	419	219	214.5	.....	.....	.....	8 —1
10.15	70	44	84	308	.....	419	211	211	.....	.....	.....	10 —0
10.45	70	44	85	307	.....	419	227	219.5	.....	.....	.....	10 —1
11.15	70	44	85	308	.....	419	212	195.5	.....	.....	.....	5 —6
11.45	70	43	85	308	.....	415	.....	203	.....	.....	.....	7 —9
12.15	70	43	85	308	.....	410	.....	201	.....	.....	.....	11 —2
12.45	70	43	85	307	.....	410	.....	201	.....	.....	.....	11 —6
1.15	70	41	85	308	.....	410	.....	201	.....	.....	.....	9 —4
1.47	70	40	85	309	.....	410	.....	Ret'd.	.....	.....	.....	10.5—10.5

LOG OF ECONOMY TEST OF EXETER BOILER.

OCTOBER 12 AND 13, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
6.00	80	400	413	69	113	70—70
6.20	"	"	415.75	73.5	112.25	70—67.5
6.40	"	"	412.25	76.5	116.50	70—66.5
7.00	"	"	410.50	69	115.25	70—67.5
7.20	"	"	411.75	80	118.75	70—66.5
7.40	"	"	409.50	78	110	70—71
8.00	"	"	410.50	72.5	113.50	70—68
8.20	"	"	413	71	117	70—66.5
8.40	"	"	413	71.25	115.25	70—68
9.00	"	"	410.5	80.50	117	70—66.5
9.20	"	"	414.75	71.25	120.25	70—69
9.40	"	"	413.50	81.50	127	70—67
10.00	"	"	408.5	72.75	102	70—69
10.20	"	"	411.75	79.50	120.50	70—70
10.40	"	"	413.75	71	116.75	70—66.5
11.00	"	"	411.75	81.50	121.25	70—68
11.20	"	"	414	71.50	118.25	70—66.5
11.40	"	414	426.5	80.50	120	70—66
12.00	"	400	411.25	75	114	70—66.5
12.20	"	"	409	84	115	70—67.5
12.40	"	"	414	74	120	70—66
1.00	"	"	415	75.25	124.25	70—68
1.20	"	"	419.25	71	117.75	70—69
1.40	"	"	429.75	71	116	70—67.5

LOG OF CAPACITY TEST OF LOWE BOILER.

OCTOBER 14, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.28							6.75
10.13	1511.5	146.25	58.5				8
10.58				1403	131.5	58	7.75
11.28	1509.5	132.75	58.5				6.5
12.07				1423.75	143	59.5	6.75
12.54	1512	130.50	59.5				6.25
1.25				1430	136	60	7.75
2.20	1505	137.75	61.5				7.5
3.02				1427	126	61	6
3.41	1508	124.75	62				6.5
4.16				1430	153.25	62.5	7.75
4.53	1512	124.50	60.5				7.75
5.28				1427	152.75	60.5	6.75

LOG OF CAPACITY TEST OF LOWE BOILER.

OCTOBER 14, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.28	70	60	92	315	.....	365	230	147.5	378	202	29.65	6.75
10.00	70	60	90	314	.....	365	239	Wood.	.....	.....	.....	8.5
10.30	70	65	92	308	.....	356	233	221	.....	.....	.....	6.5
11.00	70	65	92	308	.....	374	222	230	.....	.....	.....	7.5
11.30	70	68	98	308	.....	356	232	237	.....	.....	.....	6.5
12.00	70	68	92	309	.....	365	228	227	.....	.....	.....	7
12.30	70	68	95	309	.....	347	228	225	.....	.....	.....	6.5
1.00	70	68	98	308	.....	365	238	228	.....	.....	.....	6.5
1.30	70	70	95	308	.....	338	224	231	.....	.....	.....	8
2.00	70	70	98	308	.....	349	218	219	.....	.....	.....	7
2.30	70	70	92	308	.....	354	221	220	.....	.....	.....	7.5
3.00	70	70	92	308	.....	382	230	230	.....	.....	.....	7
3.30	70	70	95	308	.....	356	258 Ret'd.	213	.....	.....	.....	6.5
4.00	70	70	95	306	.....	361	.....	263.5 Ret'd.	.....	.....	.....	8
4.30	70	68	92	306	.....	379	.....	.....	.....	.....	.....	7
5.00	70	65	90	307	.....	347	.....	.....	.....	.....	.....	8.5
5.28	70	65	83	309	.....	356	.....	.....	.....	.....	.....	6.75

LOG OF CAPACITY TEST OF LOWE BOILER.

OCTOBER 14, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
9.40	78.75	400	414.5	60	106.25	70 —70
10.00	"	"	413.75	64	109.25	70 —70
10.20	"	"	414.5	61.5	111	70 —66.5
10.40	"	"	415.5	61	114.5	70 —65.5
11.00	"	"	413.5	63	109.5	70 —68.5
11.20	"	"	413.75	62.25	109.5	70 —67.5
11.40	"	"	414.75	62.5	112.5	70 —68
12.00	"	"	414.5	62.5	112	70 —66
12.20	"	"	413.75	64.25	110.5	70 —70
12.40	"	"	414	64.75	112.25	70 —70
1.00	"	"	411.75	66.25	107.5	70 —66.5
1.20	"	"	414.5	62.5	113.25	70 —69
1.40	"	"	411.5	63.25	103.25	70 —68
2.00	"	"	414.5	63.25	113	70 —67.5
2.20	"	"	413.5	63.50	110	70 —68.5
2.40	"	"	413.75	64	111	70 —66.5
3.00	"	"	413	63.5	110	69 —68.5
3.20	"	"	413.5	64	110.5	70 —69
3.40	"	"	413.5	63	109	70 —66
4.00	"	"	414.5	62.5	111.5	70 —66
4.20	"	"	416.25	63	119	70 —70
4.40	"	"	415.25	63	115	69.5—67
5.00	"	"	415.75	63	116.5	70 —69
5.20	"	"	414.5	64.5	114	70 —69

LOG OF ECONOMY TEST OF LOWE BOILER.

OCTOBER 14 AND 15, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
5.39	.....	.....	.....	.....	.....	.....	7.5
6.33	1501	135	60	.....	.....	.....	8
7.30	.....	.....	.....	1448	139	64.5	8
8.32	1472	160.5	66.5	.....	.....	.....	8
9.28	.....	.....	.....	1422.5	168.75	72	7.25
10.36	1479.5	155	65	.....	.....	.....	6.75
11.26	.....	.....	.....	1421.5	190.75	64	7.75
A.M.	.....	.....	.....	.....	.....	.....	.....
12.40	1472.5	137	69	.....	.....	.....	7
1.39	1470.5	929.25	73	1426	214.25	68	7.5

LOG OF ECONOMY TEST OF LOWE BOILER.

OCTOBER 14 AND 15, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES, <i>Net</i> .		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
5.39	70	56	85	309	.....	338	258	135	281.75	138.25	29.75	7.5
6.10	70	59	89	308	.....	374	224	Wood.	.....	.....	.....	9
6.40	70	59	89	306	.....	338	217	221	.....	.....	.....	8
7.10	70	59	90	308	.....	338	212	226	.....	.....	.....	7
7.40	70	58	89	309	.....	345	214	220	.....	.....	.....	8
8.10	70	59	88	309	.....	329	218	206.25	.....	.....	.....	8.5
8.40	70	59	84	309	.....	329	222	220.5	.....	.....	.....	7
9.10	70	59	84	309	.....	332	213	220	.....	.....	.....	7
9.40	70	59	85	309	.....	324	252.5 Ret'd.	207	.....	.....	.....	7
10.10	70	59	84	309	.....	325	.....	68 Ret'd.	.....	.....	.....	6.75
10.40	70	58	80	309.5	.....	320	.....	.....	.....	.....	.....	7
11.10	70	54	78	309	.....	314	.....	.....	.....	.....	.....	7.5
11.40	70	54	79	310.5	.....	326	.....	.....	.....	.....	.....	7.25
A.M.												
12.10	70	54	80	310	.....	329	.....	.....	.....	.....	.....	7
12.40	70	54	80	309	.....	320	.....	.....	.....	.....	.....	7.5
1.10	70	49	87	310	.....	329	.....	.....	.....	.....	.....	8
1.39	70	45	90	310	.....	356	.....	.....	.....	.....	.....	7.5

LOG OF ECONOMY TEST OF LOWE BOILER.

OCTOBER 14 AND 15, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
5.55	79.125	400	413.5	70	115	70 —69
6.15	"	"	410.75	74.5	113	70 —68
6.35	"	"	411.75	74.5	115	70 —66
6.55	"	"	412	71	111.5	70 —70
7.15	"	"	409.5	80	114	70.5—70
7.35	"	"	406.5	94.75	116.25	70 —69
7.55	"	"	410	80.25	114	70 —70
8.15	"	"	409.25	82.75	113.75	70 —69
8.35	"	"	418.5	67.75	129.50	70 —68.5
8.55	"	"	412.5	77.50	118.5	70 —69
9.15	"	"	412	78	117.25	70 —68
9.35	"	"	416.25	67.25	121.50	70 —67
9.55	"	"	413.5	68.50	114.5	70 —68.5
10.15	"	413.5	423	74.25	104.75	70 —70
10.35	"	400	412.75	76.50	118.5	70 —70
10.55	"	"	412.75	68.75	112	70 —68
11.15	"	"	409.25	83.75	115.25	70.5—69.5
11.35	"	"	410.25	82.75	117.25	70 —70
11.55	"	"	411.5	77.5	116.50	70 —69
12.15	"	"	409.5	86.5	119.25	70 —69.5
12.35	"	"	408.25	89.25	117.50	70 —68
12.55	"	"	411.75	76.25	122.50	70 —68
1.15	"	"	409.5	81.75	113.75	70 —67.5
1.35	"	"	410.75	81.75	117.50	70 —67.5

LOG OF CAPACITY TEST OF BABCOCK & WILCOX BOILER.

OCTOBER 18, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
2.20	.....	.....	.....	.....	.....	.....	6.5 —6
2.44	.....	.....	.....	1440.5	174.25	55	6.25—6.75
2.53	1503	150.75	55	.....	.....	.....	5.5 —7.5
3.07	.....	.....	.....	1426	152.5	56	5 —5.5
3.20	1506	191.75	56	.....	.....	.....	5.5 —6.5
3.33	.....	.....	.....	1420	174	56	5 —6
3.44	1511.25	126.25	56	.....	.....	.....	5.5 —7
3.58	.....	.....	.....	1423	177	55	5 —7
4.12	1500	117	55	.....	.....	.....	4.5 —7
4.24	.....	.....	.....	1426.25	153.75	55.5	5 —6.75
4.33	1500	143.75	56	.....	.....	.....	6.5 —7
4.50	.....	.....	.....	1436.5	149	56	5.5 —5.5
5.05	1508	129.75	55	.....	.....	.....	5.5 —5.75
5.19	.....	.....	.....	1431.5	165	56	5 —5
5.33	1516	160.25	54	.....	.....	.....	5.5 —6.25
5.53	.....	.....	.....	1425.5	135.25	56	5.5 —5
6.05	1502.5	163	57.5	.....	.....	.....	5 —5
6.13	.....	.....	.....	1185	142.75	61	6 —6
6.30	1500	155.5	58	.....	.....	.....	6 —6.5
6.48	.....	.....	.....	1433	170.25	58	5 —5
7.03	1501	171	60	.....	.....	.....	5.5 —5.5
7.23	.....	.....	.....	1421	165.5	60	5 —5
7.35	1501	139.25	60	.....	.....	.....	5.5 —5
7.53	.....	.....	.....	1419	156.75	61	5.5 —5
8.09	1500.75	154	60	.....	.....	.....	6 —6.75
8.30	.....	.....	.....	1426	170	60	5 —5
8.44	1502.5	130.5	60	.....	.....	.....	5 —5
8.55	.....	.....	.....	1428	205	61	5 —5.5
9.05	1500	136.5	59	.....	.....	.....	5 —5.5
9.15	.....	.....	.....	1420	198	60	5.75—6
9.35	1489	139.25	58.5	.....	.....	.....	6 —7
9.53	.....	.....	.....	1416.5	140.75	58	5 —5.5
10.10	1506.25	145.5	60	.....	.....	.....	5 —5.5
10.20	1437	791	60	1422.5	174	60	6.5 —6

**LOG OF CAPACITY TEST OF BABCOCK & WILCOX
BOILER.**

OCTOBER 18, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME. Hrs. Min.	STEAM-PRESSURE. Lbs.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER. Ins.	HEIGHT OF WATER IN GLASS. Ins.
		AIR. Deg.	FIRE-ROOM. Deg.	STEAM. Deg.	UPTAKE.		COAL WEIGHED OUT ON FLOOR. Lbs.	COAL CONSUMED. Lbs.	COAL FOUND IN ASHES. Lbs.	WEIGHT OF ASHES. <i>Net.</i> Lbs.		
					THER. Deg.	PYR. Deg.						
2.20	70	62	90	315	.....	482	212	410	833.5	424	29.80	6 — 6.5
2.50	70	62	90	290	.....	672	217	Wood.	.....	.....	.....	5 — 8
3.20	70	62	95	290	.....	501	209	.....	.....	.....	.....	5.5—5.5
3.50	70	66	95	290	.....	527	213	230	.....	.....	.....	5 — 6
4.20	70	68	95	289	.....	527	220	222	.....	.....	.....	4.5—5.5
4.50	70	62	92	292	.....	482	221	228	.....	.....	.....	5 — 5.5
5.20	70	62	90	297	.....	496	224	227	.....	.....	.....	5 — 5.5
5.50	70	62	95	290	.....	437	227	219	.....	.....	.....	5 — 5
6.20	70	.....	92	293	.....	437	229	221	.....	.....	.....	5.5—7
6.50	70	.....	90	291	.....	500	229	218	.....	.....	.....	5 — 5.5
7.20	70	.....	90	290	.....	512	224	211	.....	.....	.....	5 — 5
7.50	70	.....	90	300	.....	396	235	221	.....	.....	.....	5 — 5
8.20	70	.....	88	289	.....	420	235	211	.....	.....	.....	5 — 5
8.50	70	.....	90	290	.....	437	227	231	.....	.....	.....	5 — 5.5
9.50	70	.....	90	291	.....	402	223	226	.....	.....	.....	5 — 5.5
10.20	70	.....	70	290	.....	437	231	223	.....	.....	.....	6 — 6.5
.....	.....	.....	.....	.....	.....	.....	235	219	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	227	211	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	231	220	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	241	209	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	217	211	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	238	212	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	240	212	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	235	214	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	242	218	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	233	218	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	235	220	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	233	224	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	216	223	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	263	221	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	227	222	.....	.....	.....	.....
.....
.....	.....	.....	.....	.....	.....	.....	925 Ret d.	77.5 Ret'd.	.....	.....	.....	.....

LOG OF CAPACITY TEST OF BABCOCK & WILCOX BOILER.

OCTOBER 18, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
2.35	79.5	400	415.125	58	109.5	70—67.5
2.55	"	"	415.25	59	110.25	70—70
3.15	"	"	416.75	57.25	114	70—71
3.35	"	"	415.25	60	111.25	70—69
3.55	"	"	416.50	58.25	113	70—71.5
4.15	"	"	418.50	58	119.5	70—70
4.35	"	"	416.50	59	115	70—69.5
4.55	"	"	413.50	59	104.5	70—66.5
5.15	"	"	415.50	57.75	110.75	69—69.5
5.35	"	"	415.625	61.5	115.75	70—71
5.55	"	"	414.75	61.5	111.5	70—72.5
6.15	"	"	415.25	62	113.75	70—70
6.35	"	"	414.875	64.5	113.75	70—70
6.55	"	"	415.50	61.5	114.25	70—70
7.15	"	"	413.50	65.75	111	70—70
7.35	"	"	414	69	116.5	70—76
7.55	"	"	414	63.5	110.25	70—69
8.15	"	"	415.125	62	113.25	70—70.125
8.35	"	"	416.25	65	119	70—71
8.55	"	"	416	63	117	70—70.5
9.15	"	"	413.25	64	109.5	70—68
9.35	"	"	415.125	63	114	70—70
9.55	"	"	414	63.5	110.75	70—68
10.15	"	"	413.75	64	111.5	70—70.5

LOG OF ECONOMY TEST OF BABCOCK & WILCOX BOILER.

OCTOBER 18 AND 19, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERATURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERATURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
10.30	.....	.....	.....	.....	.....	.....	7 —6.5
11.01	.....	.....	.....	1431.5	140.25	62	4 —3.5
11.15	1433	146.75	64	.....	.....	.....	5 —4.75
11.33	.....	.....	.....	1429.5	136.25	68	4 —4.5
11.53	1502.5	121.75	64	.....	.....	.....	5 —4.5
12.15	.....	.....	.....	1426	136.50	61.5	4 —3.5
12.28	1503.75	156.5	62	.....	.....	.....	4.5 —4.25
12.51	.....	.....	.....	1444	137.50	62	4 —3
1.07	1504.75	167.75	62	.....	.....	.....	4.5 —4.5
1.27	.....	.....	.....	1423.25	141.25	62	4.5 —3.5
1.48	1505	176.25	62	.....	.....	.....	4.5 —3
2.10	.....	.....	.....	1449	147.25	63	4.5 —3.5
2.30	1513	150.25	62	.....	.....	.....	5 —3.5
2.51	.....	.....	.....	1433.25	150.75	62	5 —3.25
3.10	1502.5	129.75	62	.....	.....	.....	4 —3.75
3.29	.....	.....	.....	1430	173.25	62	5.25 —4
3.53	1505	150	62	.....	.....	.....	5 —3.5
4.17	.....	.....	.....	1431.25	141.25	66	5 —3.5
4.38	1500.5	162.75	66	.....	.....	.....	4.5 —3.5
4.59	.....	.....	.....	1428.25	156.25	67	5 —3.5
5.14	1500.25	131.5	68	.....	.....	.....	5.5 —4.5
5.37	.....	.....	.....	1428.50	152	68	5 —4.5
5.59	1507.5	148	66	.....	.....	.....	5 —5.5
6.16	.....	.....	.....	1426.50	173.5	65	5.5 —5.5
6.30	1513.75	157.25	66	1431	582.25	65	7.5 —6.25

55 pounds deducted for difference in starting and stopping levels.

LOG OF ECONOMY TEST OF BABCOCK & WILCOX BOILER.

OCTOBER 18 AND 19, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					Ther.	Pvr.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
10.30	70	44	90	300	.....	320	211	352	564	391	30.05	7 —6.5
11.00	70	.....	90	293	.....	302	211.5	Wood.	.....	.....	.....	3 —3.5
11.30	70	.....	90	291	.....	329	206.5	226	.....	.....	.....	4 —4
12.00	70	.....	90	292	.....	302	214	210	.....	.....	.....	4 —4.5
12.30	70	42	90	292	.....	295	82	209	.....	.....	.....	4 —4.5
1.00	70	.....	88	292	.....	302	211	205	.....	.....	.....	4.5—4
1.30	70	.....	90	288	.....	268	208.5	208	.....	.....	.....	3.5—4
2.00	70	40	88	285	.....	300	205	210	.....	.....	.....	4 —4.5
2.30	70	.....	85	287	.....	284	215	218	.....	.....	.....	3.5—4
3.00	70	.....	92	286	.....	302	200	218	.....	.....	.....	4 —3.5
3.30	70	40	82	285	.....	302	226	211	.....	.....	.....	4.5—5
4.00	70	.....	85	285	.....	311	210	224.25	.....	.....	.....	5 —4
4.30	70	.....	85	285	.....	302	209	226	.....	.....	.....	5 —4
5.00	70	40	82	284	.....	303	205	206	.....	.....	.....	3 —5
5.30	70	.....	.....	284	.....	302	208	217	.....	.....	.....	3.5—4
6.00	70	.....	82	288	.....	293	214	212	.....	.....	.....	4 —5
6.30	70	40	80	299	.....	212	210	206	.....	.....	.....	7.5—6.25
.....	.....	.....	.....	.....	.....	.....	218	207	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	218	211	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	211	209	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	224.25	215	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	270 Ret'd.	69.5 Ret'd.	.....	.....	.....	.....

LOG OF ECONOMY TEST OF BABCOCK & WILCOX BOILER.

OCTOBER 18 AND 19, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM-PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
10.45	79.375	400	415.5	63	116	70 —73.5
11.05	"	"	413.75	78.5	124	70 —70
11.25	"	"	413.25	69.5	113	70 —69.5
11.45	"	"	414.5	68	114.25	70 —67.5
12.05	"	"	415.5	67.5	119	70 —69
12.25	"	"	414.75	68	116	70 —70
12.45	"	"	415.5	65	117	70 —71.5
1.05	"	"	416	68.5	121.5	70 —67
1.25	"	"	411.25	84	121	70 —70
1.45	"	"	414.75	65	115	70 —71
2.05	"	"	413	68.5	111.75	70 —66.5
2.25	"	"	414.25	68	115	70 —68
2.45	"	"	418	69	129	70 —70
3.05	"	"	413.25	69	114	70 —70
3.25	"	"	408	79	106.25	70 —70
3.45	"	"	414	70.25	117.5	70 —69
4.05	"	"	409	86	115.75	70 —70
4.25	"	"	409.5	83.75	115	70 —70
4.45	"	"	411	77	112	70 —71
5.05	"	"	412	70.75	110.75	69.5—68.5
5.25	"	"	410.5	74.50	109.50	70 —70
5.45	"	"	411.5	75	112.75	70 —70
6.05	"	"	413	69.5	113	70 —71
6.25	"	"	413	68.5	112	70 —68.5

LOG OF CAPACITY TEST OF SMITH BOILER.

OCTOBER 21, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
10.02							8.75
11.02	1517.5	146	57				5.5
11.22				1426	157.75	57.5	6
11.45	1516	136.25	56.5				6
12.04				1428	179	59.5	6
12.24	1508.75	146	57.5				6
12.49				1429.5	148.25	56.5	6.33
1.09	1512.75	126.5	59				6
1.31				1429.5	146.75	58	5.75
1.55	1510	141.5	57				5.75
2.12				1428.5	152	57	6
2.32	1524	138.5	58				5
2.55				1425	156.25	57.5	5.75
3.16	1522.5	137.75	58.5				5.75
3.33				1417	161.5	57.5	6
3.57	1502.75	149	59				6
4.21				1422.25	155.25	58.5	5.5
4.42	1514.5	155.25	58				5.5
5.00				1419	154	59	5.75
5.16	1511.5	155	57				6.5
5.35				1410.5	141	58	6.5
5.50	1501	122.25	61				8
6.02				1417	363.5	62	8.75

7.25 lbs. leaked through blow-off.

LOG OF CAPACITY TEST OF SMITH BOILER.

OCTOBER 21, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THEER.	PLY.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
10.02	72.5	68	80	284	.....	345	212	204	409	297	29.70	8.75
10.30	70	68	74	310	.....	436	208	Wood.	.....	.....	.....	8
11.00	70	70	73	311	.....	444	213	235	.....	.....	.....	6
11.30	70	70	80	310	.....	455	206	215	.....	.....	.....	5.5
12.00	70	70	78	311	.....	440	215	225	.....	.....	.....	6.5
12.30	70	74	78	310	.....	437	216	215	.....	.....	.....	5.5
1.00	70	74	78	311	.....	437	221	216	.....	.....	.....	6
1.30	70	71	77	312	.....	446	215	218	.....	.....	.....	5.5
2.00	71	70	80	311	.....	428	213	213	.....	.....	.....	5.5
2.30	70	70	80	311	.....	446	223	220	.....	.....	.....	5.5
3.00	70	70	80	311	.....	436	211	209	.....	.....	.....	7
3.30	70	70	80	311	.....	446	243	207.5	.....	.....	.....	6.5
4.00	70	70	80	314	.....	446	230	216	.....	.....	.....	6
4.30	70	70	78	312	.....	445	232	205	.....	.....	.....	5.5
5.00	70	68	75	313	.....	437	221	210.5	.....	.....	.....	6.5
5.30	70	68	78	312	.....	437	235	218.5	.....	.....	.....	8.75
6.02	70	.....	.....	.....	.....	.....	.....	211	.....	.....	.....	8.75
.....	.....	.....	.....	.....	.....	.....	.....	210	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	73	.....	.....	.....	.....

LOG OF CAPACITY TEST OF SMITH BOILER.

OCTOBER 21, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
10.02	80.125	400	413.75	59.5	106.5	70—70
10.35	"	"	414.25	60.5	106.5	70—70
10.55	"	"	413.25	63.5	109.75	70—69
11.15	"	"	414	59	107.5	70—67
11.35	"	"	413.75	64	111.5	70—68
11.55	"	"	412.75	63	107.5	69—70
12.15	"	"	413.25	59.75	105.75	70—72.5
12.35	"	"	412	62.75	104.5	69—70
12.55	"	"	414.25	63.75	112.25	70—74
1.15	"	"	413.25	61	106.75	72—73
1.35	"	"	413.75	60	106.25	70—67.5
1.55	"	"	414.25	60.5	109	71—72
2.15	"	"	413.75	61	108.5	70—72.5
2.35	"	"	414.5	58	104	70—69
2.55	"	"	414.125	60.5	109.5	70—65
3.15	"	"	414.5	60.5	111	70—68.5
3.35	"	"	413.5	60.25	112	70—72
3.55	"	"	414	60.5	108.75	70—76
4.15	"	"	413.75	60	107	70—73.5
4.35	"	"	414	60.75	109	70—76
4.55	"	"	412.5	60	103.5	70—70
5.15	"	"	412	62.5	104.75	70—68
5.35	"	"	413.25	63.5	108	70—71
5.55	"	"	413	65	109	70—69

LOG OF ECONOMY TEST OF SMITH BOILER.

OCTOBER 21 AND 22, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
6.15	.....	.....	.....	.....	.....	.....	8
7.10	1506	191	62	.....	.....	.....	6.75
7.35	.....	.....	.....	1419.5	209	62.25	6
7.50	1503	195	64	.....	.....	.....	7.25
8.19	.....	.....	.....	1417.5	229	61.50	6
8.37	1510	135	61.5	.....	.....	.....	6.75
8.55	.....	.....	.....	1421.5	226	61.5	7.5
9.20	1514	191.5	61.75	.....	.....	.....	7.25
9.45	.....	.....	.....	1425.5	204.5	61	7
10.17	1511.5	164	62	.....	.....	.....	7.50
10.48	.....	.....	.....	1429	234.5	62.5	6.75
11.20	1509	202	62	.....	.....	.....	7
11.45	.....	.....	.....	1435	227	62.25	7
12.13	1511	189.5	60.25	.....	.....	.....	7.5
12.53	.....	.....	.....	1436	265	61.25	6.25
1.13	1522	177	61.25	.....	.....	.....	7
1.40	.....	.....	.....	1424	148.5	62	7.5
2.10	1508.5	198	61.25	.....	.....	.....	7.75
2.15	.....	.....	.....	1413	1129.00	62	8

LOG OF ECONOMY TEST OF SMITH BOILER.

OCTOBER 21 AND 22, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
6.15	77	68	78	315	.....	400	249	159.5	.....	.....	29.74	8
6.45	72	.....	80	312	.....	420	251	Wood.	.....	.....	.....	7.5
7.15	70	.....	75	310	.....	440	248	233	.....	.....	.....	6.5
7.45	70	65	78	311	.....	357	248	231	.....	.....	.....	7.5
8.15	70	65	78	312	.....	337	255	212	.....	.....	.....	6
8.45	71	62	78	311	.....	437	240	216	.....	.....	.....	7
9.15	70	62	75	311	.....	430	248	223	.....	.....	.....	7
9.45	69	64	78	310	.....	416	242	219	.....	.....	.....	7.5
10.15	70	62	80	311	.....	419	254	219	.....	.....	.....	7
10.45	70	62	75	310	.....	419	233	210	.....	.....	.....	7
11.15	70	62	75	311	.....	419	231	215	.....	.....	.....	7
11.45	70	62	75	310	.....	406	.....	210	.....	.....	.....	7.5
12.15	68	62	75	309	.....	412	.....	226.5	.....	.....	.....	8
12.45	70	62	72	310	.....	426	.....	231	.....	.....	.....	6.5
1.15	70	62	75	311	.....	419	.....	49	.....	.....	.....	7.5
1.45	70	62	72	311	.....	419	.....	.....	.....	.....	.....	7.5
2.15	70	62	72	312	.....	419	.....	.....	.....	.....	.....	8

LOG OF ECONOMY TEST OF SMITH BOILER.

OCTOBER 21 AND 22, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
6.30	80.375	400	410.75	67	104	70 —70
6.50	"	"	407	85	108.5	70 —69
7.10	"	"	411.25	74.5	114	70 —68.5
7.30	"	"	411.25	68.25	106.25	70 —70
7.50	"	"	411	70.25	107.5	70 —70
8.10	"	"	413.75	66.75	112.75	70 —71.5
8.30	"	"	412	67.75	107.5	70 —75
8.50	"	"	412	66.5	106.25	70 —69
9.10	"	"	413.25	65	110	70 —68
9.30	"	"	415.75	67	120	70 —71.5
9.50	"	"	416.75	67	122	72.5—62
10.10	"	"	412.75	64.75	107.5	70 —71
10.30	"	"	413.75	69.5	115.5	70 —69
10.50	"	"	412.75	67	110.75	70 —68
11.10	"	"	412	65.5	106.5	70 —69
11.30	"	"	412	69.75	110	70 —70
11.50	"	"	413	63	107.75	70 —69
12.10	"	"	412.75	64	108.25	68 —68
12.30	"	"	414	68	117	70 —68.5
12.50	"	"	413.25	67.5	111.5	70 —67
1.10	"	"	411.50	69.75	109	70 —70
1.30	"	"	412.25	68	109	70 —69.5
1.50	"	"	413	66.25	110.5	70 —66
2.10	"	"	411.75	65	105	70 —72

LOG OF CAPACITY TEST OF GALLOWAY BOILER.

OCTOBER 26, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
10.07	.....	.....	.....	.....	.....	.....	5.5
10.35	1434	161.25	57	.....	.....	.....	5.5
10.52	.....	.....	.....	1509	149.75	56	6
11.08	1429	146.75	56	.....	.....	.....	6
11.25	.....	.....	.....	1502	162	56	5.75
11.45	1424	156.75	56	.....	.....	.....	6
12.05	.....	.....	.....	1513.5	153.75	56	5.75
12.24	1424.75	145.25	56	.....	.....	.....	6
12.45	.....	.....	.....	1501	173.5	56	5.75
1.02	1426.25	143.25	56	.....	.....	.....	6
1.21	.....	.....	.....	1504.5	136.5	56	6
1.40	1433	143.25	56	.....	.....	.....	6
2.02	.....	.....	.....	1518.5	121.75	56	6
2.26	1420.25	153.50	56	.....	.....	.....	5.75
2.45	.....	.....	.....	1503	139	56	6
3.07	1426	145.5	56	.....	.....	.....	6
3.28	.....	.....	.....	1500.5	118	56	6
3.51	1426.25	128.25	56	.....	.....	.....	6
4.19	.....	.....	.....	1500	135.75	56	6
4.40	1429	128.25	56	.....	.....	.....	6
5.01	.....	.....	.....	1501.5	142.25	56	6
5.27	1417.75	150.75	56	.....	.....	.....	5.5
5.43	.....	.....	.....	1517.5	133	56	6.75
6.03	1422.5	134.25	56	.....	.....	.....	5.5
6.07	.....	.....	.....	1500.25	1191	56	5.5

LOG OF CAPACITY TEST OF GALLOWAY BOILER.

OCTOBER 26, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
10.07	71.5	60	78	310	.....	.....	13 Bar- rows.	278	504.5	409	29.88	5.5
10.35	70	60	68	309	.....	329	Wood	.....	.....	.....	.....	5.75
11.05	70	52	68	310	.....	338	234.5	236	.....	.....	.....	5.75
11.35	70	50	68	310	.....	320	216	236	.....	.....	.....	6.5
12.05	70	50	68	310	.....	338	213	232	.....	.....	.....	5.75
12.35	70	53	70	310	.....	311	221	233	.....	.....	.....	6
1.05	70	53	70	310	.....	338	228	211	.....	.....	.....	5.75
1.35	70	54	70	309	.....	329	224	204	.....	.....	.....	6
2.05	70	54	68	310	.....	315	.....	219	.....	.....	.....	6
2.35	70	53	68	310	.....	330	.....	205	.....	.....	.....	6
3.05	70	52	68	310	.....	329	.....	234.5	.....	.....	.....	6
3.35	70	52	68	310	.....	323	.....	232.5	.....	.....	.....	6
4.05	70	52	68	310	.....	302	.....	216	.....	.....	.....	6.25
4.35	70	50	66	310	.....	311	.....	220	.....	.....	.....	6
5.05	70	48	66	310	.....	311	.....	215	.....	.....	.....	6
5.35	70	48	64	310	.....	320	.....	237	.....	.....	.....	5.5
6.05	70	48	64	310	.....	311	.....	216	.....	.....	.....	5.5
.....	.....	.....	.....	.....	.....	.....	.....	213	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	221	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	228	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	224	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	140 Ret'd.	.....	.....	.....	.....

LOG OF CAPACITY TEST OF GALLOWAY BOILER.

OCTOBER 26, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
10.25	80.00	400	413.5	58	104.75	70—70
10.40	"	"	414	61	108.75	70—71
11.00	"	"	411	60	98.25	70—70
11.20	"	"	410.75	59.5	95.75	70—70
11.40	"	"	411	59.25	97.5	70—70
12.00	"	"	413.25	58	104	70—70
12.20	"	"	408.25	60	88.75	70—70
12.40	"	420.25	430	66	98.25	70—70
1.00	"	400	414	58.75	107.50	70—70
1.20	"	"	411.5	59.25	99.25	70—70
1.40	"	"	411.5	59.25	99.5	70—69
2.00	"	"	412.375	58.25	101.5	70—69
2.20	"	"	413.5	59	106	70—70
2.40	"	"	413	59.5	104.5	70—70
3.00	"	"	412.25	58.75	101.5	70—70
3.20	"	"	412.25	58.25	100.5	70—69
3.40	"	"	412.50	59.50	103	70—68.5
4.00	"	"	412.25	59.75	102.5	70—70
4.20	"	"	411.50	59.75	99.25	70—70.
4.40	"	"	411.75	59.50	100	70—70
5.00	"	"	411.75	58.50	99.25	70—70
5.20	"	"	409	58	89	70—70
5.40	"	"	410.75	58	95.5	70—70
6.00	"	"	412	61.50	104	70—70

LOG OF ECONOMY TEST OF GALLOWAY BOILER.

OCTOBER 27, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9-30	.....	.....	.....	.....	.....	.....	6.125
10-09	.....	.....	.....	1431.25	146.5	57	6
10-31	1503	161.75	56	.....	.....	.....	6
10-52	.....	.....	.....	1431.25	118.75	56	6
11-18	1500	172.25	56	.....	.....	.....	6
11-46	.....	.....	.....	1422	152.5	55.5	6
12-12	1500.5	171.25	55.5	.....	.....	.....	6.125
12-45	.....	.....	.....	1428	152.25	56	5.75
1-15	1503.5	160.75	56	.....	.....	.....	5.75
1-35	.....	.....	.....	1424	154.75	56	6
2-12	1500.5	129.25	56	.....	.....	.....	6
2-56	.....	.....	.....	1428	130.75	56	5.75
3-15	1501.5	145.75	56	.....	.....	.....	5.75
3-40	.....	.....	.....	1426.25	148	56	5.75
4-05	1514	209.5	56	.....	.....	.....	5.25
4-25	.....	.....	.....	1433.5	121.25	56	5.5
4-38	1489.5	165	56	.....	.....	.....	6.25
5-05	.....	.....	.....	1424	134.25	55.75	6
5-30	1502	124.5	56	1405	1253	56	6.125

LOG OF ECONOMY TEST OF GALLOWAY BOILER.

OCTOBER 27, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.30	71	48	73	311	.....	380	228	273	512.5	308	30.17	6.125
10.00	70	48	72	310	.....	318	238	Wood.	.....	.....	.....	6
10.30	70	49	71	310	.....	323	230	225	.....	.....	.....	6
11.00	70	49	71	310	.....	302	229	240	.....	.....	.....	5.75
11.30	70	52	70	310	.....	298	237	242	.....	.....	.....	6.125
12.00	70	50	71	310	.....	291	232	243	.....	.....	.....	6.25
12.30	70	51	.....	310	.....	291	230	213	.....	.....	.....	6.125
1.00	70	51	.....	310	.....	282	225	214	.....	.....	.....	6.25
1.30	70	52	70	310	.....	284	238	223	.....	.....	.....	6.25
2.00	70	53	70	310	.....	311	224	215	.....	.....	.....	6.25
2.30	70	53	70	310	.....	291	225	223	.....	.....	.....	6.125
3.00	70	53	70	310	.....	291	240	226	.....	.....	.....	6
3.30	70	53	74	310	.....	291	242	209	.....	.....	.....	5.75
4.00	70	52	72	310	.....	302	243	218	.....	.....	.....	5.25
4.30	70	51	70	310	.....	302	.....	207	.....	.....	.....	6
5.00	70	48	70	310	.....	302	.....	205	.....	.....	.....	6
5.30	70	48	70	310	.....	291	.....	148	.....	.....	.....	6.125
.....	.....	.....	.....	.....	.....	.....	.....	80 Ret'd.	.....	.....	.....	.....

LOG OF ECONOMY TEST OF GALLOWAY BOILER.

OCTOBER 27, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
9.45	80.50	400	412	57.75	100	70—70
10.05	"	"	410	60.875	95.5	70—70
10.25	"	"	413.25	58.25	103	70—70
10.45	"	"	410.75	59	95.75	70—70
11.05	"	"	412.75	58.50	101.5	70—70
11.25	"	"	412.50	58.75	101.75	70—70
11.45	"	"	412.50	58	100.5	70—70
12.05	"	"	412.50	57.50	99.5	70—70
12.25	"	"	413	59.625	105	70—70
12.45	"	"	413	58.50	103.25	70—69
1.05	"	"	413.50	57.50	104.50	70—70
1.25	"	"	412.25	59.25	101.5	70—70
1.45	"	"	412.75	58.5	102.5	70—68
2.05	"	"	412.75	59.5	103.75	70—70
2.25	"	"	415.75	59.5	113.50	70—69
2.45	"	"	412.50	59	102	70—70
3.05	"	"	412.50	57.75	101	70—70
3.25	"	"	412.50	60.75	104	70—70
3.45	"	"	412.75	60.25	103	70—70
4.05	"	"	412.25	59.25	102.5	70—70
4.25	"	"	413.50	58.50	104.5	70—70
4.45	"	"	411.25	59.5	101.5	70—70
5.05	"	"	412.75	58	103	70—71
5.25	"	"	413	58.5	103	70—70

LOG OF CAPACITY TEST OF GALLOWAY BOILER, WITH BITUMINOUS COAL.

OCTOBER 31, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.54	.....	.....	.....	.....	.....	.....	7
10.18	1501.5	118	54	.....	.....	.....	7.25
10.57	.....	.....	.....	1424	137.25	54	7
11.19	1504.5	159.75	54	.....	.....	.....	7
11.38	.....	.....	.....	1427	126.75	54	7
11.57	1504	146.75	54	.....	.....	.....	7
12.19	.....	.....	.....	1438.25	141.25	53.5	7
12.39	1505	156.75	53.5	.....	.....	.....	7
1.07	.....	.....	.....	1428.75	141	54	6.5
1.22	1505.5	120.75	54	.....	.....	.....	7
1.44	.....	.....	.....	1429	143.25	54	7
2.08	1502	137.5	54	.....	.....	.....	7
2.30	.....	.....	.....	1424	139.75	54	6.75
2.49	1503	144	54	.....	.....	.....	7
3.11	.....	.....	.....	1429.25	131.25	54	7
3.30	1509.25	173	54	.....	.....	.....	7
3.51	.....	.....	.....	1434	138.25	54	7
4.20	1504	157.75	54	.....	.....	.....	6.75
4.45	.....	.....	.....	1430	160.5	54	6.75
5.00	1508	127	54	.....	.....	.....	7
5.16	.....	.....	.....	1430	147.75	54	7
5.41	1506.5	129.25	54	.....	.....	.....	6.75
5.55	.....	.....	.....	1429	300.25	54	7

LOG OF CAPACITY TEST OF GALLOWAY BOILER,
WITH BITUMINOUS COAL.

OCTOBER 31, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.54	73	58	80	312	.....	302	.....	182	315	313	30.01	7
10.25	70	.....	70	310	.....	311	.....	Wood.	.....	.....	.....	7.5
10.55	70	59	70	311	.....	340	.....	278	.....	.....	.....	7.25
11.25	70	58	71	310	.....	363	.....	223	.....	.....	.....	6.75
11.55	70	60	71	310	.....	374	.....	196	.....	.....	.....	7
12.25	70	60	70	310	.....	374	.....	207	.....	.....	.....	6.75
12.55	70	59	68	310	.....	363	.....	319.75	.....	.....	.....	7.25
1.25	70	58	70	310	.....	363.5	.....	226	.....	.....	.....	6.75
1.55	70	59	72	310	.....	374	.....	224	.....	.....	.....	6.75
2.25	70	59	70	310	.....	392	.....	217	.....	.....	.....	7
2.55	70	59	69	310	.....	383	.....	229	.....	.....	.....	7
3.25	70	58	72	310	.....	392	.....	241	.....	.....	.....	6.75
3.55	70	57	70	310	.....	365	.....	289	.....	.....	.....	7
4.25	70	57	71	310	.....	392	.....	247	.....	.....	.....	6.75
4.55	70	56	72	310	.....	383	.....	261	.....	.....	.....	7
5.25	70	56	70	310	.....	383	.....	247	.....	.....	.....	7
5.54	70	56	72	310	.....	374	.....	233	.....	.....	.....	7
.....	.....	.....	.....	.....	.....	.....	.....	110 Ret'd.	.....	.....	.....	.....

LOG OF CAPACITY TEST OF GALLOWAY BOILER, WITH BITUMINOUS COAL.

OCTOBER 31, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
10.10	80.75	400	412	56.5	97	69-69
10.30	"	"	412	61	102	70-70
10.50	"	"	412.75	57.5	100.75	70-71.5
11.10	"	"	413	56.5	101.50	70-70
11.30	"	"	413.25	57.25	103	70-70
11.50	"	"	412.50	57	100	70-70
12.10	"	"	412	57.5	99.75	70-69
12.30	"	"	412.25	57.5	100.25	70-70
12.50	"	"	412.50	58.5	100.5	70-69.5
1.10	"	"	413	58.25	103.25	70-69
1.30	"	"	412.75	57.25	101	70-70
1.50	"	"	413.25	59	105	70-70
2.10	"	"	412	59	99.75	70-70
2.30	"	"	412.75	57.5	101.5	70-70
2.50	"	"	413.25	57.5	104	70-71
3.10	"	"	413.5	60	105	70-70
3.30	"	"	413.75	58	105	70-71
3.50	"	"	413	58	102.75	71-70
4.10	"	"	413.25	56.75	102.5	70-69.5
4.30	"	"	412.5	59	101.5	70-70
4.50	"	"	412	60.125	101.25	70-70
5.10	"	"	410.5	60.5	97.5	70-69.5
5.30	"	416.5	430	57	101.25	70-70
5.50	"	400	414.5	58.75	108.75	70-71

LOG OF ECONOMY TEST OF GALLOWAY BOILER,
WITH BITUMINOUS COAL.

NOVEMBER 1, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.27	.....	.....	.....	.....	.....	.....	6.25
10.15	.....	.....	.....	1431.5	138	55.5	6
10.38	1523.5	125.25	55.5	.....	.....	.....	6.33
11.06	.....	.....	.....	1436.5	155.75	54	6.5
11.35	1511	166.75	54	.....	.....	.....	6.5
12.05	.....	.....	.....	1438	151.5	54.5	6.25
12.32	1510.5	181	55	.....	.....	.....	6.25
12.57	.....	.....	.....	1428	140.75	54.5	6.25
1.26	1511	176	54.5	.....	.....	.....	6.25
1.53	.....	.....	.....	1433	146.25	55.5	6.25
2.20	1507.75	154.5	55	.....	.....	.....	6.25
2.45	.....	.....	.....	1436.5	152.5	56	6.25
3.20	1508.5	157.25	56	.....	.....	.....	6.25
3.57	.....	.....	.....	1433.25	155.75	55.5	6.25
4.26	1503.25	162.5	56	.....	.....	.....	6.25
4.56	.....	.....	.....	1448.5	126.25	56.5	6.50
5.27	1505	249.75	56	.....	.....	.....	6.25

LOG OF ECONOMY TEST OF GALLOWAY BOILER, WITH BITUMINOUS COAL.

NOVEMBER 1, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES <i>Net.</i>		
					THER.	PHY.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.27	73	62	83	312	.....	293	.....	315	401	200	29.90	6.25
9.55	70	65	76	310	.....	320	.....	Wood.	.....	.....	.....	6.75
10.25	70	66	77	310	.....	347	.....	236	.....	.....	.....	6.5
10.55	70	68	76	310	.....	347	.....	272	.....	.....	.....	6.5
11.25	70	70	78	310	.....	334	.....	297	.....	.....	.....	6.75
11.55	70	70	80	310	.....	329	.....	274	.....	.....	.....	6.75
12.25	70	71	79	310	.....	329	.....	230	.....	.....	.....	6.5
12.55	70	72	78	310	.....	329	.....	236	.....	.....	.....	6.5
1.25	70	74	78	310	.....	334	.....	237	.....	.....	.....	6.75
1.55	70	76	80	310	.....	340	.....	226	.....	.....	.....	6.5
2.25	70	76	80	310	.....	346	.....	231	.....	.....	.....	6.5
2.55	70	76	80	310	.....	320	.....	236	.....	.....	.....	7
3.25	69	76	80	309	.....	311	.....	68	.....	.....	.....	6.5
3.55	70	74	78	310	.....	302	.....	.....	.....	.....	.....	6.5
4.25	70	77	76	310	.....	302	.....	.....	.....	.....	.....	6.5
4.55	70	70	75	310	.....	302	.....	.....	.....	.....	.....	6.5
5.25	70	70	75	310	.....	302	.....	.....	.....	.....	.....	6.25

LOG OF ECONOMY TEST OF GALLOWAY BOILER,
WITH BITUMINOUS COAL.

NOVEMBER 1, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
9.40	81.125	400	413.25	57	102	64—64
10.00	"	"	412.75	58	103	70—70
10.20	"	"	413.50	59	104.5	70—70
10.40	"	"	413.25	56.75	102.5	70—70
11.00	"	"	413	57.5	102	70—70
11.20	"	"	413.375	57	103	70—70
11.40	"	"	413.25	58	103.5	70—69.75
12.00	"	"	414	57	104.75	70—69
12.20	"	"	412.75	59.75	103	70—71
12.40	"	"	413.25	58.25	103.5	70—69
1.00	"	"	413	58	103	70—71
1.20	"	"	413.25	57.5	103	70—69
1.40	"	"	415.50	59	111.5	71—70.5
2.00	"	"	412	59.25	101.5	70—70
2.20	"	"	414.75	58	108.5	70—70
2.40	"	"	412.75	59.5	103.75	70—70
3.00	"	"	414	60	108	70—71
3.20	"	"	412.75	59.75	103.25	70—69
3.40	"	"	413	58.5	104	70—70
4.00	"	"	412.75	59	103.25	70—69.5
4.20	"	"	412.75	59.5	104	70—70
4.40	"	"	412.75	63	107.75	70—70
5.00	"	"	411.5	60	100	70—71
5.20	"	"	417	57.5	115.5	70—71.5

LOG OF CAPACITY TEST OF ANDERSON BOILER.

NOVEMBER 7, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.48							4.25
10.25	1500	154.25	56				4.5
10.46				1428.5	132.25	56	4.25
11.03	1507	150.75	56				5.25
11.23				1428.75	154	55.5	5
11.45	1505	172	55				4
12.05				1427.75	173.25	55	4
12.20	1379.5	177	55				5.5
12.42				1418	134	55.5	5.375
1.06	1501.5	158	55.5				4.25
1.26				1423.25	150.25	54	3.5
1.44	1427.5	154.5	54				3.5
2.06				1426.5	168.75	54	3.5
2.29	1500	163.25	54				4
2.46				1428.25	153.75	54	4.25
3.07	1501	159.50	55				3.25
3.27				1428	158.50	55	4
3.49	1502.5	155.5	54				3.5
4.07				1429.25	157.75	54	3.5
4.28	1513	152.25	54				4
4.49				1445.5	167.25	55	4.25
5.08	1513	156	54				4.5
5.21				1432	153	54.5	4
5.41	1511.75	151	54				3.5
5.48				1429	695	54	4.25

LOG OF CAPACITY TEST OF ANDERSON BOILER.

NOVEMBER 7, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. . (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PHY.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.48	70	61		313	.....	275	4800	338	703.5	364	29.71	4.25
10.18	70	64		317	.....	535	.....	Wood.	.....	.....	.....	5.5
10.48	70	58		330	.....	520	.....	200	.....	.....	.....	5.5
11.18	70	58		320	.....	530	.....	200	.....	.....	.....	5
11.48	70	57		326	.....	520	.....	200	.....	.....	.....	4.75
12.18	70	56		317	.....	560	.....	200	.....	.....	.....	5.5
12.48	70	58		328	.....	500	.....	200	.....	.....	.....	4.75
1.18	70	60		325	.....	540	.....	200	.....	.....	.....	5
1.48	70	60		324	.....	520	.....	200	.....	.....	.....	5
2.18	70	62		330	.....	500	.....	200	.....	.....	.....	6
2.48	70	58		322	.....	540	.....	200	.....	.....	.....	4.5
3.18	70	58		319	.....	550	.....	200	.....	.....	.....	3.5
3.48	70	53		323	.....	550	.....	200	.....	.....	.....	4.5
4.18	70	54		325	.....	510	.....	200	.....	.....	.....	6
4.48	70	52		322	.....	550	.....	200	.....	.....	.....	6.25
5.18	70	48		315	.....	570	.....	200	.....	.....	.....	4.5
5.48	70	46		290	.....	550	.....	200	.....	.....	.....	4.25
.....	.....	.....		.....	.....	.....	.....	200	.....	.....	.....	.....
.....	.....	.....		.....	.....	.....	.....	200	.....	.....	.....	.....
.....	.....	.....		.....	.....	.....	.....	200	.....	.....	.....	.....
.....	.....	.....		.....	.....	.....	.....	192	.....	.....	.....	.....
.....	.....	.....		.....	.....	.....	.....	200	.....	.....	.....	.....
.....	.....	.....		.....	.....	.....	.....	200	.....	.....	.....	.....
.....	.....	.....		.....	.....	.....	.....	200	.....	.....	.....	.....
.....	.....	.....		.....	.....	.....	.....	200	.....	.....	.....	.....
.....	.....	.....		.....	.....	.....	.....	200	.....	.....	.....	.....
.....	.....	.....		.....	.....	.....	.....	200	.....	.....	.....	.....
.....	.....	.....		.....	.....	.....	.....	200	.....	.....	.....	.....
.....	.....	.....		.....	.....	.....	.....	32 Ret'd.	.....	.....	.....	.....

LOG OF CAPACITY TEST OF ANDERSON BOILER.

NOVEMBER 7, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
9.55	82.00	400	411.25	57.5	96	70—69
10.15	"	"	410.5	57.5	94.75	70—70
10.35	"	"	411	58	95.75	70—77.5
10.55	"	"	412.75	57	104	70—70
11.15	"	"	411.75	57.5	98.75	70—70
11.35	"	"	412	56.5	99.5	70—70
11.55	"	"	412	58	99	70—70
12.15	"	"	414	56.5	103.5	70—69
12.35	"	"	411.5	57	97	70—67
12.55	"	"	412.25	57	99	70—70
1.15	"	"	411	56.5	96	70—68
1.35	"	"	411.5	57.25	97.5	70—72
1.55	"	426.5	439.75	56.5	98.5	70—68
2.15	"	400	412.75	58	101.75	70—70
2.35	"	"	413	57	102	70—66
2.55	"	"	413.5	57.25	104.25	70—72
3.15	"	"	.....	.....	.....	.....
3.35	"	"	413.5	58	104	70—70
3.55	"	"	411.75	57.25	98	70—66
4.15	"	"	409.75	56.5	90.5	71—73
4.35	"	422	435.25	56.25	98.75	72—79
4.55	"	400	412.25	57.25	100.5	70—70
5.15	"	"	412.5	57.25	99.5	71—71
5.35	"	"	412	58	100.25	70—71.5

LOG OF ECONOMY TEST OF ANDERSON BOILER.

NOVEMBER 8, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.24	.....	.....	.....	.....	.....	.....	7
10.08	1503.5	154.5	54	.....	.....	.....	5.5
10.35	.....	.....	.....	1442	140	54	4.75
10.57	1511.5	161.75	54	.....	.....	.....	4
11.19	.....	.....	.....	1436.5	162.75	54	4
11.43	1419	171	54	.....	.....	.....	5.5
12.10	.....	.....	.....	1420.5	155.25	54	6
12.44	1506.5	151	54	.....	.....	.....	4.5
1.07	.....	.....	.....	1439.5	157.75	54	5.25
1.35	1509	151	54	.....	.....	.....	7.5
2.16	.....	.....	.....	1431.5	137.75	54	4.5
2.43	1500	157.5	54	.....	.....	.....	4.5
3.09	.....	.....	.....	1437.5	171	54	4
3.32	1432.5	151.25	54	.....	.....	.....	5
3.59	.....	.....	.....	1439.25	152	54	5.25
4.39	1516	153.25	54	.....	.....	.....	4
4.52	.....	.....	.....	1425	157.75	54	5.5
5.21	1500	178.75	54	.....	.....	.....	6.25
5.24	.....	.....	.....	1405	1209.75	54	7

LOG OF ECONOMY TEST OF ANDERSON BOILER.

NOVEMBER 8, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THER.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.24	70	50	.....	312	.....	315	3204	292	443.5	260	29.83	7
9.54	70	48	.....	339	.....	495	.....	Wood.	.....	.....	.....	5.5
10.24	70	50	.....	337	.....	500	.....	204	.....	.....	.....	4.25
10.54	70	54	.....	325	.....	410	.....	200	.....	.....	.....	5.75
11.24	70	55	.....	323	.....	430	.....	200	.....	.....	.....	6
12.24	70	56	.....	324	.....	495	.....	200	.....	.....	.....	4.5
12.54	70	56	.....	319	.....	415	.....	200	.....	.....	.....	6
1.24	70	57	.....	329	.....	380	.....	200	.....	.....	.....	6.25
1.54	70	57	.....	320	.....	350	.....	200	.....	.....	.....	5.5
2.24	70	57	.....	322	.....	400	.....	200	.....	.....	.....	6
2.54	70	58	.....	319	.....	400	.....	200	.....	.....	.....	5
3.24	70	56	.....	329	.....	380	.....	200	.....	.....	.....	6
3.54	70	57	.....	320	.....	400	.....	200	.....	.....	.....	5.25
4.24	70	58	.....	315	.....	400	.....	200	.....	.....	.....	4
4.54	70	57	.....	320	.....	400	.....	200	.....	.....	.....	5.5
5.24	70	56	.....	320	.....	400	.....	200	.....	.....	.....	7
.....	.....	.....	.....	.....	.....	.....	.....	200	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	200	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	70 Ret'd.	.....	.....	.....	.....

LOG OF ECONOMY TEST OF ANDERSON BOILER.

NOVEMBER 8, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
	Hrs. Min.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
9.30	82.00	400	.....	.....	.....	.....
9.50	"	"	410.75	54.75	92.25	71-68
10.10	"	"	410.5	56	92	70-70
10.30	"	"	412.5	55.75	99	70-65
10.50	"	"	413.25	56	101.75	70-67
11.10	"	"	412.25	55.75	99.75	70-67
11.30	"	"	410.75	55.5	94	70-69.5
11.50	"	"	409.75	55.5	90	70-71
12.10	"	"	410.25	56	91	70-65
12.30	"	"	411.75	54.75	96	70-70
12.50	"	"	412	55.75	99	70-70
1.10	"	"	413.25	55.75	102.25	70-71
1.30	"	"	410.50	55.5	92.25	70-70
1.50	"	"	411.75	55.5	96.25	70-70.5
2.10	"	"	410.50	56	92.25	70-66
2.30	"	"	412.25	55.75	98	70-67
2.50	"	"	412.25	56	98	70-65
3.10	"	"	412	55.75	98	70-65
3.30	"	"	412	56	98	70-65
3.50	"	"	410.5	56	95	70-65
4.10	"	"	411.5	56	96	70-70
4.30	"	"	411.75	56	97	70-68
4.50	"	"	409.25	56	92	70-70
5.10	"	"	411	56	94	70-65

LOG OF CAPACITY TEST OF PIERCE BOILER.

NOVEMBER 10, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.36	Between two cocks.
10.22	1500	154.25	52	.....	.....	.....
11.10	.....	.....	.....	1425	146.75	53
11.57	1500	184	52	.....	.....	.....
12.26	.....	.....	.....	1425	139.75	52
12.59	1500	148.75	52	.....	.....	.....
1.38	.....	.....	.....	1425	139.25	52
2.12	1500	160.25	52	.....	.....	.....
2.48	.....	.....	.....	1425	143	52
3.27	1500	96	52	.....	.....	.....
4.00	.....	.....	.....	1425	152.5	52
4.31	1500	137	52	.....	.....	.....
5.11	.....	.....	.....	1425	135	52
5.36	1500	498	52	.....	.....	.....

10 lbs. dripped from gauge cocks.

LOG OF CAPACITY TEST OF PIERCE BOILER.

NOVEMBER 10, 1876.

No. 2.—GENERAL OBSERVATIONS.—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
TIME.	STEAM-PRESSURE.	TEMPERATURES. (Fahrenheit.)					COAL AND ASHES.				BAROMETER.	HEIGHT OF WATER IN GLASS.
		AIR.	FIRE-ROOM.	STEAM.	UPTAKE.		COAL WEIGHED OUT ON FLOOR.	COAL CONSUMED.	COAL FOUND IN ASHES.	WEIGHT OF ASHES. <i>Net.</i>		
					THEIR.	PYR.						
Hrs. Min.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.36	70	48	Boiler in the open air.	322	.....	350	2400	200	394	174.3	29.79	
10.06	70	48		310	.....	440	.....	200	.....	.....	.....
10.36	70	48		308	.....	430	.....	200	.....	.....	.....
11.06	70	48		311	.....	450	.....	200	.....	.....	.....
11.36	70	48		309	.....	455	.....	200	.....	.....	.....
12.06	70	48		312	.....	460	.....	200	.....	.....	.....
12.36	70	48		311	.....	470	.....	200	.....	.....	.....
1.06	70	48		308	.....	475	.....	200	.....	.....	.....
1.36	70	47		310	.....	470	.....	200	.....	.....	.....
2.06	70	46		310	.....	450	.....	200	.....	.....	.....
2.36	70	46		309	.....	470	.....	200	.....	.....	.....
3.06	70	46		311	.....	470	.....	200	.....	.....	.....
3.36	70	45		311	.....	480	.....	163 Wood.	.....	.....	.....
4.06	70	44		310	.....	470	.....	.....	.....	.....	.....
4.36	70	46		312	.....	450	.....	.....	.....	.....	.....
5.06	70	44	311	.....	430	.....	.....	.....	.....	.....
5.36	70	46	310	.....	420	.....	.....	.....	.....	.....

LOG OF CAPACITY TEST OF PIERCE BOILER.

NOVEMBER 10, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
9.40	82.875	400	412.25	54	94.5	70—73
10.00	"	"	410.5	53.25	86.25	70—69
10.20	"	"	412.5	54	95	68—68
10.40	"	"	414.25	54.25	103	70—55
11.00	"	"	413.25	55	100.75	70—68.5
11.20	"	"	413	55	99.75	70—63.5
11.40	"	"	412	55	95.75	70—53
12.00	"	"	410.75	54.25	92	60—65
12.20	"	"	409.5	55	86	70—64
12.40	"	"	414	54	100	70—63
1.00	"	"	410.5	54	89	70—63.
1.20	"	"	412.5	53.75	92	70—71.5
1.40	"	"	412	53.5	94.5	70—75
2.00	"	"	414.5	53.75	102	70—66
2.20	"	"	413.25	55.25	99	70—65
2.40	"	"	414.25	54	102	70—68
3.00	"	"	413.5	54	97.75	70—66
3.20	"	"	414.25	54.25	101.25	70—68.5
3.40	"	"	414.25	54	100.5	70—66
4.00	"	"	414.25	54	100.5	70—68
4.20	"	"	413.5	54	98.25	70—65
4.40	"	"	415	54	102	70—62
5.00	"	"	416.25	54.25	108	70—75
5.20	"	"	412.25	55.75	93	70—67

LOG OF ECONOMY TEST OF PIERCE BOILER.

NOVEMBER 11, 1876.

No. 1.—RECORD OF FEED-WATER.

1	2	3	4	5	6	7	8
TIME.	TANK A.			TANK B.			HEIGHT OF WATER IN GLASS.
	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	INITIAL WEIGHT.	FINAL WEIGHT.	TEMPERA- TURE.	
Hrs. Min.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
9.04							Between two cocks.
9.56	1500	148.5	53				
10.47				1425	143.75	52	
11.38	1500	140.25	53				
12.26				1425	149	53	
1.18	1500	102.75	54				
2.09				1425	133.25	53	
3.10	1500	152	53				
4.04				1425	150.75	52	
4.48	1500	156	52				
5.04				1425	785	52	

LOG OF ECONOMY TEST OF PIERCE BOILER.

NOVEMBER 11, 1876.

No. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
TIME.	WATER.			TEMPERATURES. (Fahrenheit.)		STEAM- PRESSURE.
	WEIGHT OF BARREL.	INITIAL GROSS WEIGHT.	FINAL GROSS WEIGHT.	INITIAL.	FINAL.	
Hrs. Min.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
9.10	83	400	415.5	50.5	95	70—60
9.30	"	"	414	54	98.5	70—63
9.50	"	"	411.75	55	95	70—63
10.10	"	"	414.50	55	100	70—60
10.30	"	"	416.25	54	108.5	70—70
10.50	"	"	413	54.5	98.75	70—67
11.10	"	"	414.5	55	103.5	70—58
11.30	"	"	413.5	54	101.75	70—65
11.50	"	"	414	55	104	70—67
12.10	"	"	414.75	54.75	102	70—66
12.30	"	"	411.5	54.5	94.5	70—65
12.50	"	"	414.75	54	102	70—65
1.10	"	"	414	54	100	70—58
1.30	"	"	413.75	54.25	101	70—62
1.50	"	"	415.5	54.5	106	70—64
2.10	"	"	413	55.5	98.75	70—65
2.30	"	"	413.25	55	100	70—65
2.50	"	"	413.25	55	100.5	70—65
3.10	"	"	414	54.5	103	70—65
3.30	"	"	412.5	55.5	98	70—65
3.50	"	"	411.75	55	94	70—65
4.10	"	"	413.75	54	101.75	70—70
4.30	"	"	414	55	101	70—65
4.50	"	"	413.25	55	99	70—65

TRIAL OF STEAM FIRE-ENGINES.

PROF. FRANCIS A. WALKER, *Chief of the Bureau of Awards:*

SIR,—I herewith transmit the Report of the Trials of the Steam Fire-Engines, made in the Bureau of Machinery under the direction of Messrs. Porter, Belknap, and Brugsch, a Committee of the group.

Very respectfully,

HORATIO ALLEN,

Chairman Group XX.

HORATIO ALLEN, ESQ.,

Chairman Group XX., Judges International Exhibition:

SIR,—We herewith transmit with our approval the Report of the Trials of the Steam Fire-Engines, made in the Bureau of Machinery under the direction of this Committee, by Mr. Wellington Lee, an expert appointed for the purpose, on the recommendation of the group.

Very respectfully,

CHAS. T. PORTER,
JOSEPH BELKNAP,
EMIL BRUGSCH,

Committee of the Judges of Group XX. on Fire-Engine Trials.

TRIAL OF STEAM FIRE-ENGINES.

PHILADELPHIA, October 10, 1876.

MESSRS. CHAS. T. PORTER, JOS. BELKNAP, E. BRUGSCH,
Committee Group XX. (Motors, Pneumatic and Hydraulic Apparatus).

GENTLEMEN,—About the 27th day of August I was notified that I had been appointed to take charge of the proposed trials of fire-apparatus, including especially steam and chemical fire-engines.

I have to report that the programmes agreed upon were printed* and a copy forwarded to each exhibitor, together with a letter inclosing a tracing for nozzle-pipe, with a request that one be made for each of the engines they proposed to work at the trial. (See Exhibit A.) The exhibitors were at the same time notified that they would be expected to furnish their own leading-hose and at least thirty-five feet of suction-hose, and that the ground on which the engines would stand was about seven feet above the water to be lifted. They were also notified that their engines would be numbered respectively in the order of their application for space at the Exhibition.

The numbering of the engines was as follows :

Silsby Manufacturing Co., Seneca Falls, N. Y.	. . . .	No. 1.
" " " " "	. . . .	No. 2.
B. S. Nichols & Co., Burlington, Vt.	. . . .	No. 3.
La France Manufacturing Co., Elmira, N. Y.	. . . .	No. 4.
J. D. Ronald, Chatham, Ontario	. . . .	No. 5.
Clapp & Jones, Hudson, N. Y.	. . . .	No. 6.
" " " " "	. . . .	No. 7.
L. Button & Son, Waterford, N. Y.	. . . .	No. 8.
Amoskeag Manufacturing Co., Manchester, N. H.	. . . .	No. 9.
" " " " "	. . . .	No. 10.
Clapp & Jones, Hudson, N. Y.	. . . .	No. 11.

After notice to the exhibitors, the engines, except No. 11, were

* Exhibit A.

weighed on August 16, and all except Nos. 10 and 11 subjected to a hydrostatic test, in accordance with the programme.

This gave the basis for the pro-rata nozzles. (See Exhibit C, Table A.) No. 6 drew a stay-bolt and was slightly bilged in the fire-box; it was withdrawn for repairs, and again satisfactorily tested on August 29 to two hundred and forty pounds.

Those in charge of No. 9 asked for a working pressure of one hundred and fifty pounds, and an attempt was made to carry the test to three hundred pounds, but failed at two hundred and thirty on account of a leak in the upper part of the boiler. It was withdrawn for repairs, but not again tested, having been withdrawn before the trial began.

At first queries were raised by the builders as to the propriety of testing the boilers to double the working pressure, instead of fifty per cent. above, in accord with the "Government Rule." The answer was, that "the Government boilers are not subject to so many strains,"—the extent of some of such strains being, from the nature of the case, unknown. This answer seemed satisfactory to all except No. 3, in which one hundred and fifty pounds was named as the working pressure, but the boiler leaked at two hundred and fifty-five pounds.

On Saturday, September 2, the Amoskeag Company withdrew their engines from the trial, not being satisfied with the conditions adopted for the government of the trials.

On the 4th of September all the engines except Nos. 9 and 10 took positions at the dock, and the day was spent in getting ready for the real work, which was to begin on the 5th. Two lines of leading-hose were laid from each engine, one being led from the discharge-gate to a small house, erected for the purpose, where the butt was capped and a pressure-gauge attached. The butts and gauges were placed in a row, so that all the gauges were brought under the immediate inspection of Mr. W. F. Newell, who was appointed to record the water-pressures and time, and also to prepare and give out the blanks for steam-pressure and length of stream. To the butt of the other line the regulation nozzle-pipe was attached and secured to a frame placed on the Rider Life-Raft Company's life-raft, so arranged that all the pipes were in the same plane and could be easily changed from one angle of elevation to another in a few moments. To avoid mistakes, each pipe was numbered to correspond with the number of the engine to which it belonged. Mr. P. R. Voorhees was appointed by the Chief of the Bureau of Machinery, Chief Engineer J. S. Albert, U.S.N., to record the steam-pressures and to keep an account of the fuel used. Each gauge was numbered to correspond with the engine to which it was connected. On the table in front of each gauge was placed a

sheet with blank spaces for recording water-pressures and time. Pressures were recorded every minute when any were indicated, and when no pressures were indicated zeros were used, and the added amount divided by the number of observations recorded during the trial. The coal and wood were weighed and furnished to the engines as required by the exhibitors, a strict account being kept of all furnished throughout the trials. The lubricating oil was furnished by Mr. F. S. Pease, of Buffalo, New York, of which an account was also kept. (Table B.)

The pro-rata nozzles were made of round disks of brass, in all cases two and a half inches in diameter and one-quarter of an inch thick, to suit the regulation nozzle-pipes (see Exhibit C); the thickness being reduced to one-eighth of an inch at the orifice. These disks were made by Messrs. Pratt & Whitney, exhibitors in Machinery Hall; they also measured and marked the diameters of all nozzles used at the trials, and these are believed to have been perfectly correct.

The first trial commenced September 5, 1876. At 10 A.M. fires were laid with shavings, wood, and coal, with the understanding that no other combustibles should be used. All being ready, a signal was given to light torches, and at 11.16 A.M. the signal was given to light fires.

The pressure of water and steam maintained by each engine, and also the size of the pro-rata nozzles used at the different trials, is set forth in Exhibit B. The first trial ended at 12.08 P.M.

The second trial commenced at 2.35 P.M., September 5, with the medium nozzles. Engine No. 8 withdrew, having broken its pillow-block. For the work done by each engine, reference is made to Exhibit B. The trial ended at 3.32 P.M.

The third trial commenced at 3.48 P.M., September 5, the small-sized nozzles being used; observations of water-pressure being taken about once a minute throughout the trial. (Exhibit B.) The trial ended at 4.39 P.M.

The sixth trial* commenced September 6, at 11.41 A.M. At 12 o'clock Engine No. 4 burst its air-chamber, and recorded but little pressure for the remaining thirty-eight minutes of the trial. No. 5 did not work satisfactorily, seldom indicating more than forty-five pounds pressure. The trial ended at 12.47 P.M.

The fifth trial followed trial No. 6 immediately without laying fires,

* The trials on September 6 were made in the order of 6, 5, and 4 of the programme, because the large-size nozzle of Engine No. 1, necessary for trial No. 4, could not at the time be found.

commencing at 2.08 P.M., Engines Nos. 4 and 5 being still unable to work. The trial ended at 3.10 P.M.

The trial announced as the fourth, but made the sixth, commenced at 3.22 P.M., with the same conditions as in trial No. 1. Engines Nos 4 and 5 made no record, having been disabled in the previous trial. Nos. 1 and 3 used a double line of leading-hose, terminating in one nozzle. The trial ended at 4.21 P.M.

The seventh trial was for vertical stream, and commenced at 10.13 1/2 A.M., September 7, with large nozzles. Engine No. 4 was not ready until 10.44 A.M., but made a good record from that time to the end of the trial. No. 3 had several mishaps, and did not make a good record. The trial ended at 11.14 A.M.

The eighth trial was for vertical stream, and followed trial No. 7 without laying new fires; the nozzles were of medium size. Toward the end of the trial the suction-strainer of Engine No. 3 became clogged with grass that had been washed in from the lawn. An allowance has been made for this, giving the engine a record for the trial equal to the best that it made during the play for an equal length of time. The trial ended at 1.07 P.M.

The ninth trial was for height and quality of stream, and commenced at 1.33 P.M., September 7, following trial No. 8 without laying new fires. The small-sized nozzles were used. The trial ended at 3 P.M.

The tenth trial commenced at 10 A.M., September 8. Steam-Engines Nos. 1, 3, 4, and 7, Babcock Chemical Engine, No. 2, and Babcock Hook-and-Ladder Truck, No. 1, were the only ones reported ready with horses for the street trial. No. 3 finally declined, and the horses were sent away. The exhibitors laid fires to suit themselves. Each engine took on water, suction-hose, coal, tools, and four men; in fact, all they proposed to use in working the engines at the dock on their return.

The Babcock Chemical Engine, No. 2, was loaded with two tanks of water, chemicals for a half-hour's work on return, two hundred feet of leading-hose, ten feet of suction-hose, and three men. The engines were first trotted over the course to be run, and with the load so made up were weighed. (See Table D.) On return, it was found that No. 1 had been thrown off from one spring, which caused some delay in giving the word to start. It was claimed by Mr. Silsby that some extra pieces of rubber had been put under the bearing on the top of the ordinary spring, which had caused the derangement. The pieces were removed in about half an hour. One of the horses of No. 1 had cast a shoe, and as it was then after 12 o'clock it was determined to adjourn the run until 1 o'clock. At 1 o'clock the horses

of Engine No. 1 had not returned, but the word was given to start. The order and time of starting of each engine and their subsequent return will be found in Table D. It will be observed that No. 1 left much later than the others, and made the run in about the same time as No. 7, and that Nos. 7 and 4 had in the mean time made a long record of pressures. It is to be remembered that it would have been perfectly fair to have given the word to start as soon as the weighing was done (which was originally intended), when the result would have been still worse for No. 1, so it cannot be unjust to take the record as it stands, and it has been so made up. The record made by the Babcock Engine, No. 2, will be found in the report on chemical apparatus, but it may be proper to state that it returned over 3.75 minutes ahead of all others, having started 0.25 minutes behind No. 7 steamer, and beaten it 3.75 minutes, and No. 4 by 8.25 minutes; it also commenced working 45 seconds after its arrival at the dock, being ahead of all competitors by 30 seconds. (See Table D.)

It was found impracticable to continue the street trials on account of the inferior weight and quality of the horses and the long, heavy road through the grounds; one run seemed to exhaust their strength and endurance. The trial, therefore, continued at the dock until 3.41 P.M. It had been the understanding from the first day of the trial that the trials would be concluded on Saturday, September 9,* by a sweepstakes, in which the engines were to use any kind of nozzle and work at any pressure desired. As soon as the work was finished for the day, all parties interested were informed that such a trial would begin in the morning.

The Director-General, however, sent a request that the trials should come to an end that evening, on account of complaints of the smoke in the grounds and buildings. The trials proposed for the fifth day were therefore omitted.

REMARKS ON THE TRIALS.

A careful analysis of the facts brought out at the trials will justify the theory upon which the programme and rules were made, viz., the engine that is capable, at a fire, of exerting the greatest amount of power in proportion to its weight (other things being equal) is the best. It is to be observed that all builders of steam fire-engines act upon this theory, whether they acknowledge it or not. Several of them have reduced parts of their engines to nearly the limit of the elastic strength of the material used when subject to predictable strains

* See rules for trial No. 13, Exhibit A.

incidental to the steam- and water-pressures they are to employ, without reference to the unknown shocks and strains to which machines of this kind are liable. It is true that there have not been many general catastrophes or explosions, but the bill of repairs has not always been as light as it ought to be. Again, all of the engines offered for competition make the boiler, more or less, the backbone of the whole structure. The bed-frame is bolted to it in all cases, and in Engines Nos. 3, 9, and 10, both the steam- and water-cylinders are made fast to the boiler. In Nos. 1, 2, 4, 5, 6, 7, and 11, the working strains do not affect the boiler, the carrying strains only being transmitted through the bed-frame.

These facts are not mentioned as condemning the method of fastening to the boilers, but to demonstrate, in a measure, the propriety of testing the boilers to double the working pressure. What has been said of boilers is true of all other parts of the engine, and if the builders so boldly cut down the weight of every item that enters into the construction of an engine, why should not weight be made the basis of classification? As stated above, the object of the trials has been to ascertain which engine, according to its weight, would do most work in a given time, and whether it is at the same time equal, superior, or inferior to its competitors in other respects that may be of importance in making up a good engine.

So far as relates to the pro-rata power of the different engines, reference to Tables A and B will show clearly which engines are best in this respect. The one question that remains is, whether the engines exerting the greatest amount of power per weight were equal in other respects. To answer this question fairly and with perfect accuracy may at first seem difficult in the absence of facts that a thorough street trial would have established.

There are, however, enough data within reach upon which to base a practical and accurate conclusion. Take, as a starting-point, the engine that showed the best record, and compare the design, proportion, and manner of constructing its carrying parts with like features of other engines inferior in indicated power at the trials, viz.: 1st, wheels; 2d, axles; 3d, bed-frame; 4th, carrying-springs; 5th, boiler-hangings.

No. 7, the engine that has the best working record, is at the same time quite as strong in all respects (pro-rata to its work) as any of the engines, except the iron wheels on Nos. 1, 2, and 5. Therefore, No. 7 being the most powerful, and at the same time as strong, for street service, it remains to find where the excess of weight is in the engines of less pro-rata power. In comparing the different boilers, it is evi-

dent that Nos. 1, 2, 3, 4, 5, 8, 9, and 10 are heavier than Nos. 6, 7, and 11; this accounts for most of the excess of weight in the other engines. The question now remaining is, whether the boilers of Nos. 1, 2, 3, 4, 5, 8, 9, and 10 are as much better, as they are heavier. A larger portion of the heating surface of the boilers of Nos. 3, 5, 8, 9, and 10 is made up of plates, and so these are necessarily heavier than those of 6, 7, and 11, where a larger proportion of heating surface is made up of tubes, while the boilers of Nos. 1, 2, and 4 are heavier because, though of the same general plan of construction as No. 7, they contain a much larger amount of heating surface. To decide this question it is necessary to consider what constitutes a good steam fire-engine boiler. The most important points may be stated as follows: 1st, strength; 2d, good circulation; 3d, sufficient super-heating surface to insure dry steam; 4th, durability; 5th, accessibility for repairs; 6th, large area at water-line; 7th, a long range from low to high water; 8th, large flue area; 9th, non-liability to explosion.

By a reference to the cuts of the various boilers, it will be seen that that of Engines 6, 7, and 11 is certainly equal to any other boilers in all respects. It will be seen that the boilers of Nos. 1 and 2 are heavier than those of 6, 7, and 11 only because they are larger.

The relative merits of construction were decided by making a list of all the parts that enter into the construction of an engine and considering each item by itself: 1st, as to general appearance, finish, and design; 2d, convenience for working; 3d, durability; 4th, strength and security; 5th, comparative excellence in arrangement; 6th, accessibility for repairs.

The value of each item was expressed by numbers from 1 to 10, which, added together, were divided by the number of observations made, and the average so obtained was entered in the general average account under the head of "construction marks." When one engine had an apparatus attached which another had not, the one that had such part was given an appropriate mark, and that which had none received a zero. The comparative excellence of such parts as wheels, axles, bed-frame, braces, thickness of boiler-plates, staging, and springs, has been determined by mathematical calculations based on measurement. (See Table B.) When the pro-rata strength of the axles is considered, the boiler and bed-frame are in all cases treated as a beam having two points of support, varying in distance apart in the different engines. All the facts are summed up and expressed in what are called "construction marks."

As a further illustration of the methods of investigation, some of the facts relating to the hangings of Nos. 1 and 4 are given. In No.

1 the side-bars of the frame are five and one-half by three-fourths inches, fastened to the boiler by four bolts, with a lap on the boiler of seven inches; the bearings, one hundred and two inches apart, are strengthened by a brace from the boiler to the frame, leaving the frame at an angle of 23° .

The side-bars of No. 4 are five and seven-eighths by three-fourths inches, and are fastened to the boiler by six bolts and a lap on the boiler of fourteen inches, the brace leaving the frame at an angle of 28° and the bearings being eighty-nine inches apart.

Now, a simple statement of these facts makes it apparent that No. 4, as a beam, is the stronger; but by reference to Table E it will be seen that No. 1 has the stronger axles; which is right? Three of the four bolts that fasten the side-bars of No. 1 to the boiler commenced leaking before the trial was finished, showing weakness or bad workmanship, or both. The above questions have all been settled, and the results go to make out the construction averages, making it unnecessary to construct more tables for this branch of the investigation.

It will be observed by reference to the water-pressures indicated at trials No. 1 and 4 by Engine No. 1, that there was a difference, although the nozzles were of the same size. It will also appear by reference to the record of other engines that a greater difference exists between them and No. 1 at the first trial than at any which followed. It was also noticed at the time of the trial that, although Engine No. 1 was working under a greater pressure than any other, its stream was inferior to several of them; this was particularly noticeable when the stream of No. 1 was compared with those of Nos. 2, 3, 4, 7, and 11, both as to quality and length of stream, while in several other trials it was superior in quality and length. After carefully comparing these facts, but one conclusion can be arrived at: that in trial No. 1 there must have been some unusual obstruction between the nozzle of Engine No. 1 and the working part of the pump, and that in justice to the other exhibitors the error should be corrected by striking out at least a portion of the average of No. 1 at the first trial. By the most careful examination that can be made, this excess cannot be less than fifty-three pounds, but the account has been made up by deducting fifty pounds. During the sixth trial Engine No. 1 drew the coupling off the leading hose next the engine, which caused a diminution of the record; but at the same time No. 7 was flooded by this accident to such an extent as to nearly extinguish its fire. No. 1 caused the accident but suffered most; and as the contest was between these two competitors, and no others are practically affected by the mishap, no effort has been made to rectify the record.

Nos. 9 and 10 (Amoskeag) having been withdrawn from the trial, there is no record of work to compare with the other engines; and, as No. 9 is a self-propeller, it cannot be compared with the other engines if the theory upon which the trials is based is adhered to, nor has any more satisfactory method of classing them been proposed. No. 10 has the strongest wheels of any of the engines; the axles are about as strong, the bed-frame is among the strongest; the boiler is heavier than that of Nos. 3, 5, or 8, because thicker iron is used in its construction; it is heavier than that of Nos. 6, 7, or 11, because more plate-iron is used; and it is about the same weight with Nos. 1, 2, and 4, because the latter use more fire surface pro-rata to the entire weight of engine. By a careful analysis of its construction, size, and relation of water- and steam-cylinders, and the plan and capacity of the boiler, a tolerably accurate conclusion may be arrived at as to its relative merits compared with the other engines. By reference to Table F, it will be seen that the area of the steam-cylinder is nearly three times that of the water-cylinder, giving a much less capacity for forcing large quantities of water (other things being equal) than is possessed by the other engines in question.

The limit to the capacity of a reciprocating pump is the number of times the cylinder can be filled in a given period. The extreme limit is the velocity at which the water will follow the piston, taking into account the obstruction of valves and waterways and the number of times the direction of the water is changed in getting into and out of the pump, and also the angle at which the change is made. In making up the account the same rules have been applied as in the case of the engines that took part in the test, so far as construction is concerned. As to what was possible for Engine No. 10 to do in the way of working, it is clear that it could not have done better than No. 7. It probably would have indicated a higher pressure on the small stream, but not any better on the medium stream, and not so good on the large stream. The relation between the heating surface of the boiler and the steam-cylinder, as well as the relation between the water- and steam-cylinders, should be considered in connection with the waterways, valves, number of revolutions per minute, and amount of water to be handled. Now, it is difficult to see the advantage that No. 10 could have over No. 7 as regards any stream but the smallest. Relatively to weight of boiler, it has not so large an area of valve-opening, its waterways are not so short and direct, the steam-cylinder is smaller, and the pump must run faster. It has also less heating surface.

The working parts of this engine are not as accessible for operating

and repairs as several of the others; this is partly owing to the steam- and water-cylinders being placed vertically, which brings the fly-wheels directly in front of the working parts of the engine. The difficulties incidental to these arrangements have been in some degree obviated by an ingenious device for oiling. This consists of a large fountain or dish, so located that the oil is conducted through small tubes to the eccentric, cranks, crank-pins, slide-blocks, and main shaft-journals. The flow of oil is regulated by cocks that are more or less accessible when the engine is not in motion. Whether these inconveniences are compensated for by any advantages in the arrangements that create the necessity for such additional parts is another question that has been treated separately, the foregoing remarks being intended to apply to the subject of accessibility and convenience in working and adjustment. The reasons for placing the engine and pump in a vertical position are as follows: 1st, to allow the front wheels to interlock, so as to be able to turn the engine short; 2d, to secure steadiness while working; 3d, to shorten the steam connection.

The builder of Engines Nos. 6, 7, and 11 claims that, by transmitting the working strains of the engine through the centre of the bed-frame and counterbalancing, steadiness is more nearly attained, and that their steam connections are as short as in any other engine, and also that greater strength and security are obtained with much less cost for construction and weight of material.

The steadiness of No. 7 while working at the trials, and its plan of construction, show it to be equal to any in this respect, except the rotary engines.

The trials and measurements show that Engine No. 3 has a strong frame and axles, a large, heavy boiler, a very large area of grate surface, large steam- and water-cylinders, and long, variable water-line. These relations and conditions are favorable to throwing large, long streams for a short length of time, but not for continuously maintaining high pressures on long lines of hose or small nozzles, which is the same thing. The parts to be handled for working purposes are quite accessible, and for facility of repairs this is among the best of all engines.

Engine No. 4 is, in a general way, a strong, well-built rotary engine, but seems to have been put into the trial without the proper preliminary tests. The difference in the weight of this engine as compared with Silsby's No. 1 is accounted for in the greater thickness of the iron boiler-plates (Silsby using steel), and a somewhat heavier bed-frame, and some little difference in the working parts of the engine and pump. In stoking, too much coal was kept on the grate.

The general appearance of Engine No. 5 was good, and favorably impressed all interested in this kind of machine, but its record proved unsatisfactory. Early in the trial such serious defects were developed that those having it in charge found it impossible to keep it at work when wanted, although some hours were allowed each day for repairs. In the construction of this engine the builder has copied parts of several of the American engines: 1st, the boiler and the details of the pump and engine are from the Amoskeag; 2d, the bed-frame and arrangement of steam- and water-cylinders are a copy of the engine of Cole Bros., as is also the method of attaching the frame to the front axle; 3d, the wheels are from the Silsby Manufacturing Company. Many of the minor details are also a copy of other engines. There was something that was not copied, for either of the above-named engines habitually does better work than was done by No. 5 on this trial.

No effort has been made to decide whether rotary or reciprocating engines are the better, further than is determined by the record of the trials, and by a consideration of the one hundred and eighty-five points relating to construction.

Engine No. 8 has some features which differ from all others: 1st, the location of the steam- and water-cylinders; 2d, the two capacities of the pump, which are obtained by working a small piston through a larger one or working both at the same time, the object being to use the large area on large streams and the smaller one on small streams, or long lines of hose. These cylinders are engaged or disengaged at will by an outside lever. It is certainly desirable to attain this double capacity, and the arrangement for the purpose is ingenious and effective; but the question whether it is not attained by too great cost and increased liability to get out of order is not quite so clear. It may be observed that this engine made a good record at the first trial previous to its break-down, and that the break was not owing to this arrangement. As to the first-named point, it may be said that by placing the engine and pump forward over the front axles, the wheels may interlock or turn under without adding so much to the length of the engine as in the case of the others, where the front wheels turn forward of the engines and not around.

WATER-PRESSURE THE TRUE TEST OF EFFICIENCY.

But little, if anything, can be learned of the merits of an engine from a consideration of the length and quality of stream. Certainly all that can be thus approximately learned can be definitely and accurately ascertained, and with less labor, by observing the size of nozzle used and the water-pressure maintained while the engine is worked.

The consideration of length and quality of stream was made a point in the programme, mainly for the purpose of clearly demonstrating the difficulty (it might be said, fallacy) of testing engines in this way. Pressure, other things being equal, determines the distance a stream should be projected. The causes that affect a stream are mainly outside of the engine, and may be stated as follows :

1st. Kind of nozzle, good or bad.

2d. Consideration of the column of water in leading-hose, as it arrives at the nozzle, as to whether it has a spiral motion or not.

3d. Whether or not the water has a pulsating motion.

4th. The condition of the air as to density.

5th. The direction and velocity of the wind.

6th. The size of the stream.

The simple statement of these points shows how difficult it must be to form an accurate conclusion as to the comparative merits of engines, particularly if they vary much in size and plan of construction. A stream may be so small, or a nozzle so bad, that no amount of pressure will throw it two hundred feet; while it may be so large and the nozzle so perfect that a very moderate pressure will throw it two hundred and fifty feet, while the small engine might be a good one and the larger one quite deficient in excellence. It is clear that all the points are chargeable to the engine; but one, the third, is caused by the engine, and nothing else. The absurdity of testing engines by length of stream was manifested throughout all the trials.

The course of the horizontal streams was along the margin of the lake, and, except the first one hundred feet, was about parallel with it. Pairs of stakes were placed along the shore ten feet apart,—the shore-line parallel with the line of the streams, the outer line of stakes parallel with the first line and about twenty feet back from the margin, and so placed that the line drawn from one stake to its pair would be at right angles with the line of play. The distance of each pair of stakes from the nozzles was so marked that the distance thrown by any engine could be constantly observed and recorded. The height of the vertical streams was determined by the use of the theodolite, located several hundred feet from the nozzles. An officer was de,

tailed by Mr. H. J. Schwarzmamm, Engineer of the Exhibition grounds, with two assistants, who were engaged for two days in observing and recording the facts relating to length of stream, and his results so obtained are set forth in the tables.

Each day there was some wind; and, though not very strong, it was of sufficient force to cause a variation of twenty-five to thirty-five feet in the longest streams, that could not be chargeable to anything else. A reference to the water-pressure, indicated and recorded at the time these variations were noticed, often contradicted the variations as regarding the stream of any engine so examined. The method of testing an engine through long lines of hose and length of stream is also imperfect, and some of the reasons why may be stated as follows, viz.: 1st. There is generally some difference in the smoothness of different makes of hose. 2d. Some hose requires more pressure to force it out into a cylindrical shape than others. 3d. One line of hose may have more or shorter turns than another. 4th. There is a liability to accidental obstructions, such as rags, strings, paper, straw, coal, gravel, etc. 5th. A spiral motion may be given to one stream of water and not to another, which would make a difference in the distance thrown, other things being equal.

CONCLUSION.

A careful analysis of the facts brought out at the trials, and calculations based upon actual measurements of various parts of all the engines in competition, afford sufficient data to warrant the following conclusion:

Silsby's No. 1 at all the trials did better than any of the rotary engines, and better than all the reciprocating engines, except Nos. 7 and 11.

Clapp & Jones's engines, Nos. 7 and 11, made the best record, and were the only ones, except Nos. 2 and 6, that went through all the trials without an accident sufficiently serious to interrupt their regular work. These (Nos. 7 and 11) are in most respects the strongest engines and the most perfect in detail and finish. It is also quite clear that No. 7 is superior to all others in nearly every point that concerns the making up of a good steam fire-engine. It has done better work than No. 1, has stronger axles, a stronger bed-frame, and is better secured to the boiler; it is more accessible for repairs, is as convenient to work; its wheels appear to be strong enough, and in workmanship and appearance it is equal, if not superior. It uses less oil and less fuel. The bed-frame of No. 1 is so arranged that the front wheels may be turned under, and it has iron wheels, which will

be considered of more or less importance. An effort has been made to place a just comparative value on both of these points.

It is considered proper to compare the aggregate work of Silsby's Nos. 1 and 2 with Clapp & Jones's Nos. 6, 7, and 11, and Table C has been devoted to a statement of these facts.

CHEMICAL ENGINES.

With regard to the trial of chemical fire-apparatus, I have to report that the programme annexed* was, on the 19th of August, forwarded to the different exhibitors of this kind of apparatus, together with a letter requesting them to make a nozzle-pipe after a tracing furnished them.

The engines were numbered in the order of their acceptance, as follows:

Champion Fire Extinguishing Co.	No. 1.
Babcock Manufacturing Co.	No. 2.
W. K. Platt & Co.	No. 3.
Walton Bros.	No. 4.
Chas. T. Holloway	No. 5.

Preparations were made to furnish chemicals, and a place for the different exhibitors to build houses to be filled with combustibles, in accordance with the programme. The same theory was adopted for classing and testing as in the case of steam fire-engines; that is, the engine capable of taking the most extinguishing material to the fire with the least weight is the best, other things being equal.

The rules for testing were designed to decide, as far as possible, all the points involved, viz.: 1st, the weight of the engines, to be decided by weighing them without any kind of supplies; 2d, the relative amount of work that an engine could do, by playing each engine through a nozzle pro-rata to its weight, the engine making continuous play through the largest nozzle being the best in that respect; 3d, which engine could be soonest put to work on arriving at a fire; 4th, the comparative economy in the use of chemicals, to be ascertained by keeping an account of all the chemicals used and comparing the work with said account; 5th, the best mechanical arrangement for handling and carrying chemicals, best arrangement of engine for repairs, liability to derangement, and comparative excellence in adaptability to the largest range of circumstances in working at all kinds of fires, to be determined by a separate examination of every part of the engine, taken in connection with the work done during the trials.

* See Exhibit A.

All exhibitors, in one way or another, signified their approval of the programme, but no one except the exhibitors of Engine No. 2 came forward at the day of the trial. The agent of the Babcock Manufacturing Company, Mr. Smith, said he was ready to do all and anything the Judges might direct, but if there was no competitor he would like to avoid the expense of putting up a building. It was decided that it was not a trial to prove the utility of chemical engines, but the comparative merits of the different builds, and that he need not build the house, but that the engine could go in competition with the steamers, and run with them on the street, and the time of starting, arriving, and working at the dock be noted.

It was worked sufficiently to show its capacity for keeping a continuous stream, with the size of nozzle and results set forth in Table B, annexed. It will be observed that it made better time on arriving and getting to work than any of the steamers, making it perfectly apparent to all who saw the performance that it could be taken over the ground at a much higher speed than a steamer, and that it could be brought into action on arriving at a fire in much less time.

To ascertain the comparative merits of the various engines, the same method of investigation was adopted as in the case of steam fire-engines, viz.:

1. General appearance and finish.
2. Proportion of parts in relation to the whole engine as to strength and symmetry.
3. Accessibility of parts for working.
4. Accessibility of parts for repair.
5. Convenience in working and handling.
6. Comparative security in handling and carrying chemicals.
7. Certainty of quick action when wanted.
8. General adaptation to work under the greatest variety of circumstances.
9. Weight as per work done.
10. Character of driver's and other attendants' seat.
11. Character of liquid when in operation.
12. Regularity and continuity of stream.
13. Economy in use of chemicals, as shown by chemicals used and work done.
14. Amount of time required to get to work.
15. Amount of time required to charge.
16. Amount of time required to re-charge.
17. Non-liability to get out of repair.
18. Facility for repairing parts.

19. Arrangement for carrying signal-bell and operating the same.
20. Method of arranging and operating the brake.
21. Mounting and dismounting.
22. Amount of discharge-hose carried.
23. Convenience in winding hose.
24. Convenience in paying out or unwinding the same.
25. Number of men required to operate the machine in proportion to the work done.

CONCLUSION.

From a careful consideration of the foregoing facts and trials, it may be fairly concluded that the Babcock Engine, No. 2, is the best in most of the points that go to make up a chemical fire-engine. Generally, it is the best arranged, is the lightest, has the best arrangement for handling chemicals, is most convenient for working, is most accessible for repairs, and is best adapted to a variety of work.

Respectfully submitted,

WELLINGTON LEE, *Expert*.

GOULD STEAM FIRE-ENGINE.

The boiler of this engine is known as the vertical tubular with a submerged smoke-flue. The advantages claimed for it not found in other steam fire-engine boilers will be understood by reference to Fig. 1, namely: 1. The fire-box, B, is made tapering, giving an in-

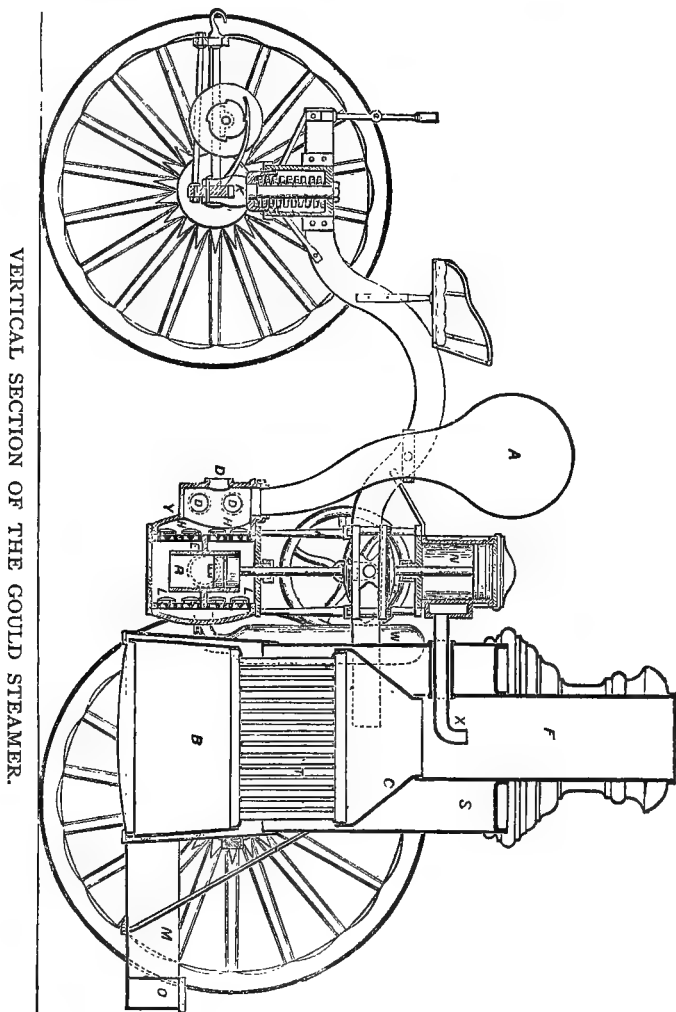


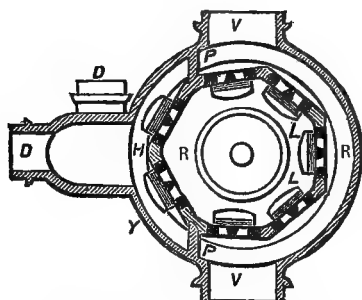
FIG. 1.

VERTICAL SECTION OF THE GOULD STEAMER.

creased area of grate, which, added to the inclination of the sides of the fire-box over the fire, increases, it is claimed, the steaming qualities of the boiler without adding to its weight, while the water-leg, being larger at the top than at the bottom, gives a better circula-

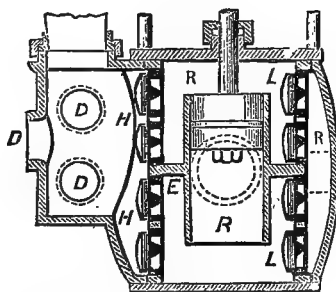
tion than if it were straight. 2. The smoke-box, C, is conical in shape, and is made in one sheet; this form, it is said, gives the greatest strength, the best draft, takes up less room in the steam space, and makes one less joint in that part of the boiler most liable to leak. The steam-cylinders of the double engines are in one casting with the steam-chest opening on the front. In the single engines the steam-chest opens on the side, so that in either case it is easy to get at the valves when necessary. The eccentrics are forged solid with the crank-shaft, thus avoiding the liability of slipping, which is not an uncommon occurrence where they are not solid with the shaft. The pump is shown in Figs. 2 and 3, the former being a horizontal section and the latter a vertical section. It consists of the

FIG. 2.



HORIZONTAL SECTION OF PUMP.

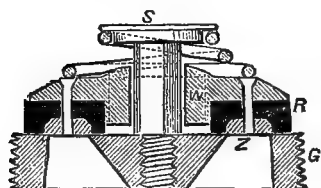
FIG. 3.



VERTICAL SECTION OF PUMP.

casing Y, and the cylinder and valve-plate R, the latter being in one casting of composition. By taking off the bottom cover of the pump, the valve-plate and cylinder can be dropped down, so that the valves can all be seen at once, and repaired if necessary, and the cylinder put back in place. The partitions of the pump are shown at P, P, Fig. 2, and E, Fig. 3.

FIG. 4.



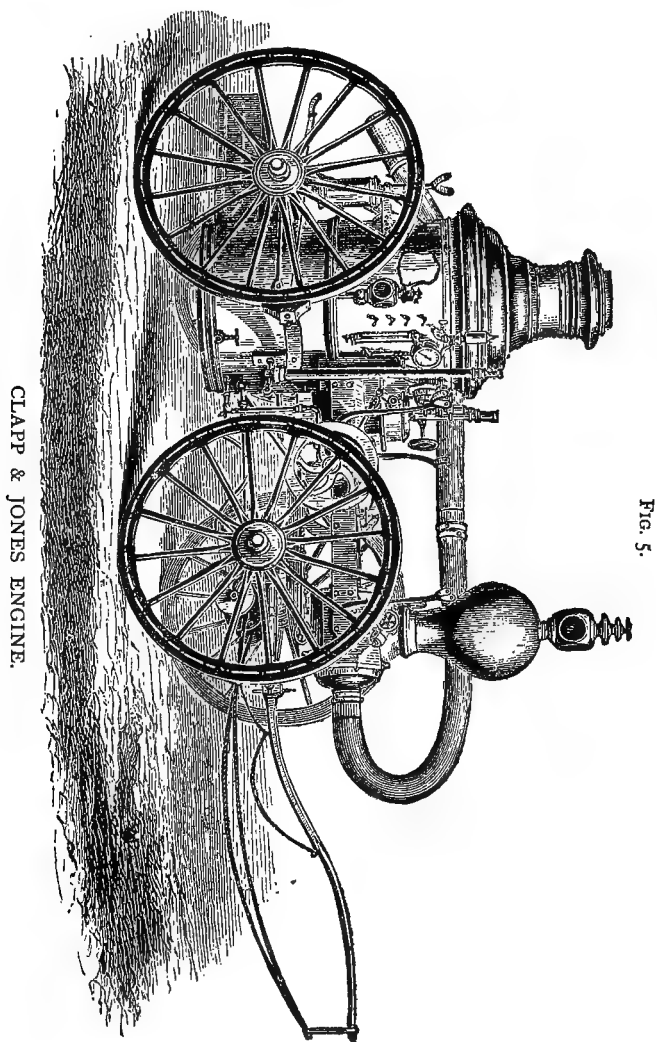
PUMP-VALVE.

The arrangement of valves upon the vertical valve-plate, as shown in Fig. 4, gives large area of suction and discharge with but little lift of valves. The valve-slides upon the stud, S, are guided by the knife-edged projections, W, which effectually prevent the valve from sticking up because of sand or gravel. The pump-packing is composed of leather,

which is formed into a cup shape, there being two to each piston, placed back to back; the piston is thus self-packing, and with ordinary care is always ready to draw the water.

CLAPP & JONES STEAM FIRE-ENGINE.

A vertical section of the boiler of the engine is seen in Fig. 9. It is of the vertical kind, with both fire- and water-tubes, the fire-tubes, J, extending from the crown sheet of the fire-box up through the top

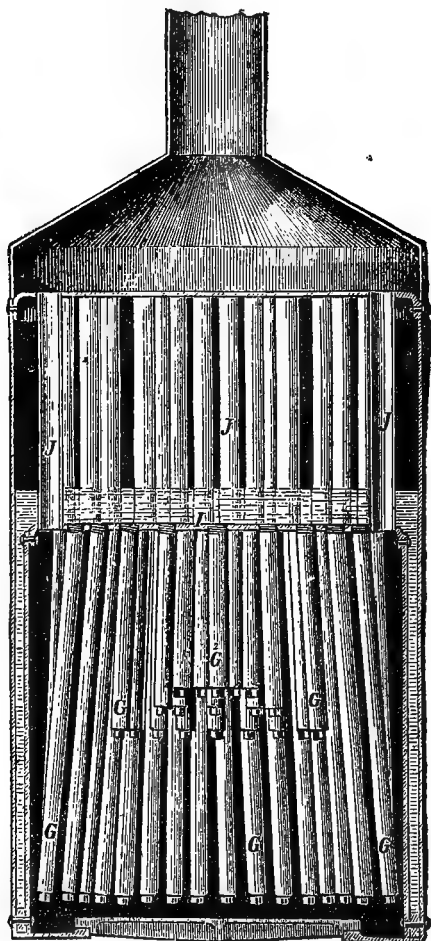
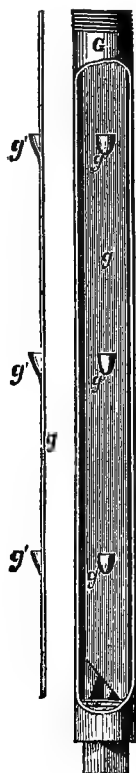


of the shell, and the water-tubes, G, G', G'', being pendent from the crown of the fire-box. The outer rows, G, G, of water-tubes extend nearly to the bottom of the fire-box, and surround rows of shorter

tubes, G' , G' , and G'' , G'' , which are about half the length of the outer row. One of these water-tubes, detached from its position, is shown in Fig. 7, and is broken away to exhibit the arrangement provided for the circulation of the water. Fig. 6 is a transverse section

FIG. 6.

FIG. 9.



of the tube, showing the diaphragms: one of these is seen detached in Fig. 7, and they are so arranged as to form a triangle when inserted in the tubes. In this way the water is isolated into thin films or sheets, so that the generation of steam will be very rapid,—the diaphragm serving to establish return passages for water to supply the place of that converted into steam and carried up by steam. By the

arrangement of openings g' , g' , much of the water lifted will be allowed to return to the return passage, without passing all the way up to the top of the tube.

The pump is so arranged that by taking off the heads (which can be done very quickly) the valves are taken out at the same time.

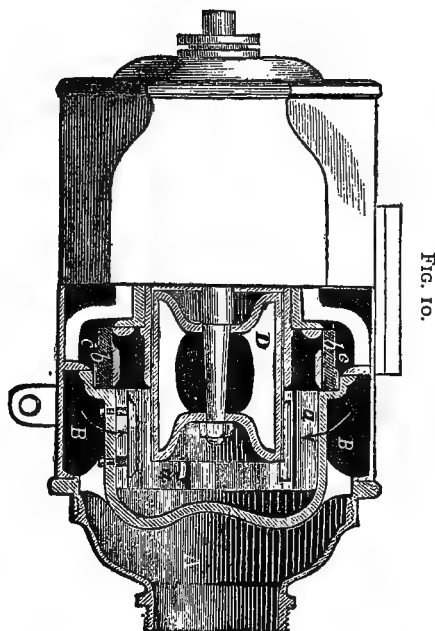


FIG. 10.

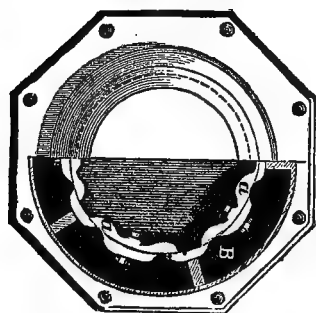


FIG. 11.

This makes it convenient for repairs or cleaning out, if it should be required.

By introducing the water in the centre of the front head (as shown in the cut), the advantage is attained of an equal distribution of the water through the annular space to all sides of the pump-cylinder and valve-chambers, making a very free water-course to the valves. The

further advantage is attained of retaining water enough in the pump to make sure of drawing water when first starting the engine, even on very high lifts, thus entirely avoiding the necessity of any connection with the boiler for the purpose of "priming" the pump, or of providing any other means of doing what some fire-engine-builders and pump-makers have found it necessary to do, that is, to put water or grease into the pump either before or at the time of starting on very high lifts.

The air-chambers are so placed on the pump, in connection with the water-passages, that it will bear working at a very high speed.

Fig. 10 gives a side elevation of the pump, one-half of it showing an external view, while the other half is shown in section on a vertical line through the centre.

Fig. 11 shows an end view with the upper half shown in section on a line through the centre of the suction-valves, which is about one-fourth of the length of the pump from the end. The same letters refer to like parts in both figures. A is the front head, made with a chamber or water-space to receive the water as it comes into the pump through the suction-hose; this chamber is connected to the Chamber B (which is also on the suction or induction side of the pump) by the annular space around the valve-chamber. D is the pump-plunger, which is made entirely of metal, water-packed; *a, a, a*, are the induction-valves through which the water passes from the chamber B to the pump-cylinder. The shape of these valves is shown in Fig. 11; *b, b*, is the eduction or discharge-valve, which is a ring of india-rubber, put on the inner end of the pump-head, but is enough longer than the head to reach over the annular space and lap over on a ring on the cylinder which forms a part of the valve-seat, the water passing through the annular space into the discharge-chamber, *c, c*; this chamber extends all around the pump-cylinder. The discharge air-chamber and discharge-gates are connected with this chamber. The pump is double-acting, and both ends are alike, so that the valves from one end will fit perfectly in the other.

SILSBY STEAM FIRE-ENGINE.

The boiler is of peculiar construction. It is vertical and both tubular and tubulous; *i.e.*, there is an extended heating and circulating surface of water-tubes, in addition to the ordinary smoke-flues. A (Fig. 14) is the fire-box with water walls. From the flue-sheet hang circulating water-tubes, C C, closed at the lower ends, and tightly screwed into the sheet. These tubes are inclined so as to best receive

SILSBY ENGINE, No. 1.

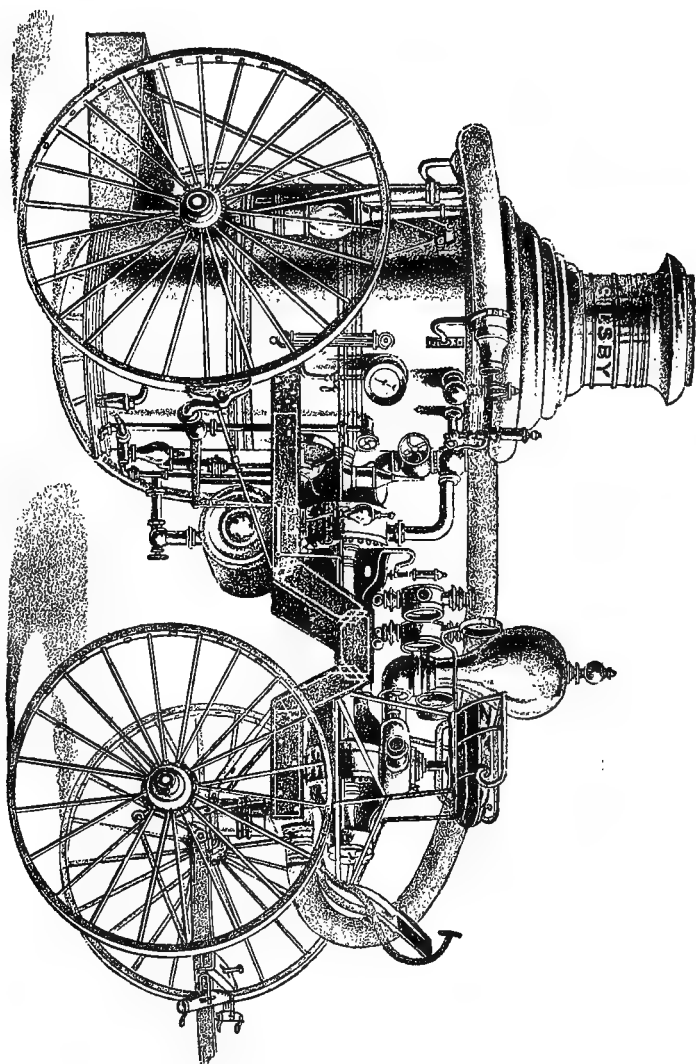


FIG. 12.

SILSBY STEAM FIRE-ENGINE.

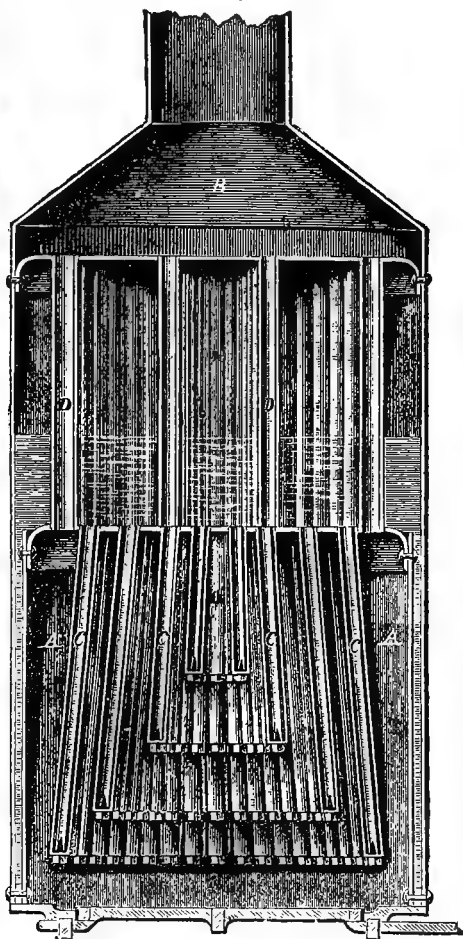
		DESCRIPTION.
Capacity . . . . .	.	600 gallons of water per minute.
Number of streams . . . . .	.	From one to four.
		DIMENSIONS.
Height . . . . .	.	9 feet 3 inches.
Length (with pole) . . . . .	.	23 feet.
" (without pole) . . . . .	.	13 feet 4 inches.
Width . . . . .	.	6 feet.
Front wheels . . . . .	.	4 feet in diameter.
Hind " . . . . .	.	5 " "

the heating action of the fire. One of them is shown detached in Fig. 13. Within each of these tubes is a light iron tube, down which the water passes after being heated by contact with the flues D D. Becoming highly heated and evaporated, the resultant steam escapes

FIG. 13.



FIG. 14.



through the openings at the bottom, passes upwards through the annular space between the inner and outer tube, and becomes still further heated. Reaching the upper chamber it is further heated and dried by the smoke-flues D. The boiler may be fed with cold water if desired, although a special heating apparatus enables the feed-water to enter the boiler from the tank at a temperature of 212° , resulting in great speed and economy in steaming. The boiler can also be fed

directly from the main pump. The water-flues can be taken out and replaced in a few minutes; and the smoke-flues, being fastened from the crown sheet to the upper head of the boiler, are easily accessible by removing the dome, should repairs become needed; as it is not necessary to tear the boiler to pieces.

The engine consists of a pair of corrugated cams running together within an elliptical steam-tight case. The steam enters at A and exhausts at B, turning the two cams C and D in its passage (Fig. 15). The ends of the long teeth are packed by blocks of metal inserted into the grooves and pressed out by springs. These can be taken out and replaced in a few minutes by means of an opening in the sides of the case, preventing the necessity of taking the engine apart. The sides of the cams are turned to fit the case, and while steam-tight, are so arranged that not only is due allowance made for contraction and expansion, but any little wear there may be, after years of service, can be easily taken up in a very short time.

FIG. 15.

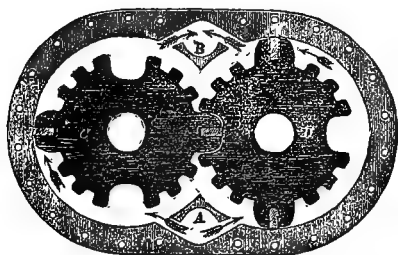
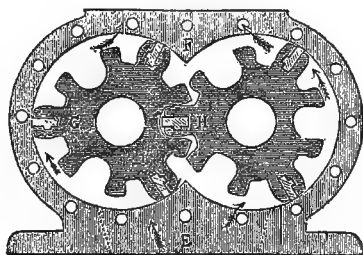


FIG. 16.



The pump is on the frame in a line with the engine, and its construction is similar (Fig. 16). Each cam in the pump has three long teeth instead of two, which insures a steadier motion. The packing is the same. The cams G and H are fixed on steel shafts, which are coupled to the shafts of the engine. The action between the engine and pump is direct, the outside gears steadying the motion and equalizing the pressure. As will be seen by the above cut, the water enters at E, and discharges at F.

FIG. 17.

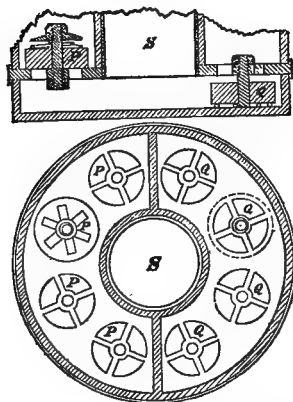
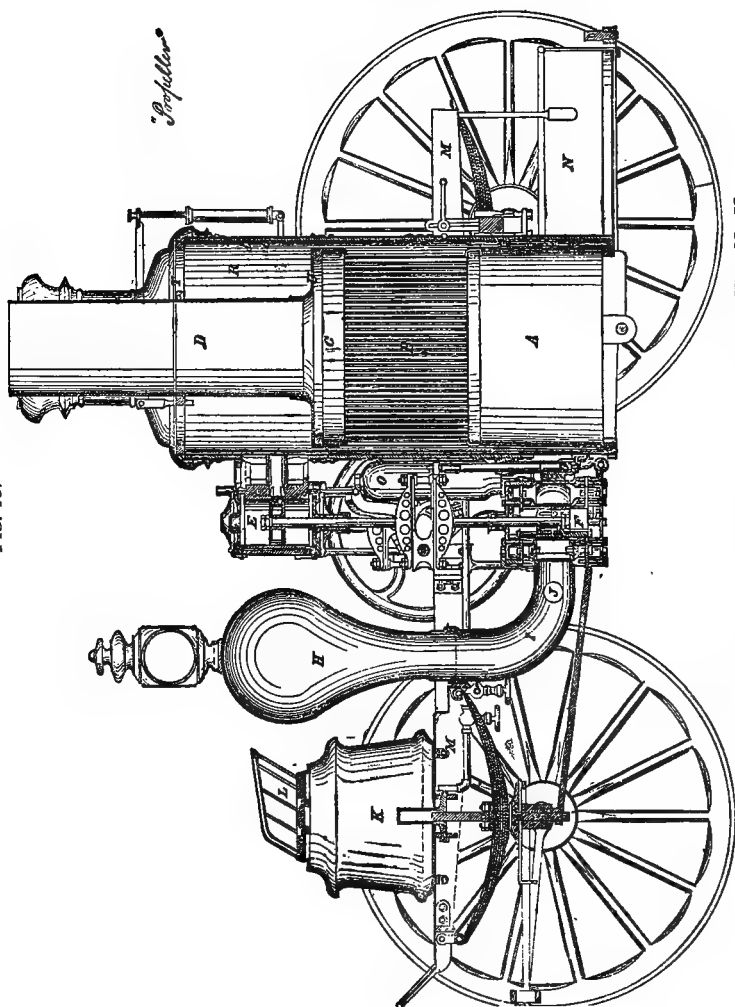


FIG. 18.



AMOSKEAG MANUFACTURING CO., MANCHESTER, N. H.

EXHIBIT A.

[No. 222.]

UNITED STATES CENTENNIAL COMMISSION.

INTERNATIONAL EXHIBITION, 1876.

PHILADELPHIA.

GENERAL PROGRAMME OF THE TRIALS OF COMPETING STEAM FIRE- ENGINES, AND OTHER FIRE-APPARATUS.

1. These trials will be four in number, and will take place on four consecutive days, commencing on the fourth day of September. On the first day the engines will be tested for capacity and endurance in delivering water through three different-sized nozzles furnished by the Judges, and varying in area for each engine, according to the weight, with boiler filled.

The second day will be devoted to trials for distance and character of stream.

The trials on the third day will be for height and character of stream.

These trials will be conducted on the grounds of the Exhibition, and each will be continued for three hours, and as much longer as the Judges may direct.

On the fourth day the engines will be tested by three runs over a course of at least a mile, to be fixed by the Judges; each run to be followed by a play of not less than thirty minutes, in which, with the exception of leading-hose, nothing shall be used that has not been carried over the course. Engineer and all assistants must make the trips on the engines.

2. Bituminous coal will be used as fuel. Fuel, and whatever may be required to start the fire, will be weighed to each competitor.

3. All engines will play through at least one hundred feet of hose, but each competitor may play through whatever size or kind of hose, or through as many lines uniting in one nozzle, as he may choose. Each exhibitor will furnish his own hose.

4. Each engine will lift its water the same distance.

5. For the trials on the second and third days, each competitor will select his own nozzle. On each of these trials three nozzles shall be used by each one, varying in size from the smallest to the largest used by them on the first trial, respectively.

6. Pressure-gauges for water will be furnished and connected by the Judges.

7. The engines which are intended to compete will be weighed previously to the trial; first, without water or equipments; second, with boiler filled to proper working level; and, third, with equipments complete for service. Each competitor will fix his water-level as he desires, and will be required to start from such level on each trial.

8. No engine shall be ruled out on account of any accident, but shall resume work as soon as possible, and shall be credited with all work done within the time of trial.

9. Each competitor shall fix the highest steam-pressure at which his engine is to be

worked, and this shall not be exceeded on the trials. All boilers and pipes will be subjected to a hydrostatic test of double the working pressure.

10. A detailed programme, with rules to be observed, will be furnished to competitors previous to the trials, in which provision will be made for trial of other fire-apparatus.

11. The trials will be conducted under the supervision of a Committee of the Judges of Group XX., consisting of Messrs. Chas. T. Porter, Emil Brugsch, and Joseph Belknap, assisted by Mr. Wellington Lee, of New York.

A. T. GOSHORN, *Director-General*.

FRANCIS A. WALKER, *Chief of Bureau of Awards*.

[No. 221.]

GENERAL PROGRAMME FOR THE TRIALS OF COMPETING CHEMICAL AND PNEUMATIC FIRE-ENGINES AND APPARATUS.

1. These trials will commence on the sixth day of September, and, excepting the runs, will be conducted within the grounds of the Exhibition.

2. The trials will be four in number. The first trial will be for pressure and continuity of stream, through regulation nozzles, and for economy in the use of chemicals; and will be continued for half an hour, and longer if the Judges shall direct. The second trial will be for length of stream, for completeness of chemical combination at the first discharge, and for the promptness with which the apparatus can be brought into action. The third trial will be for efficiency in extinguishing fires. The fourth trial will consist of three runs over a course of at least a mile, to be fixed by the Judges, each run to be followed by a play of fifteen minutes.

The apparatus will be charged previous to the commencement of each run, and all equipments will be carried, and all attendants required to operate it must make the trips.

3. The engines will be weighed before the trials; first, without water, chemicals, or equipments; second, with one charge of water and chemicals; third, with water, chemicals, equipments, and additional chemicals sufficient for a half-hour's play.

4. Pressure-gauges will be furnished by the Judges, which are to be attached to the tanks by hose.

5. The Judges will have proper nozzles prepared for the first trial, varying in area for each engine, according to its weight, with one charge of water and chemicals.

6. On trial for length of stream, each competitor may use whatever nozzle he prefers.

7. All plays will be through at least one hundred feet of hose.

8. Chemicals will be furnished and weighed to the competitors as required by them.

9. Water for charging will be drawn from a tank or pond.

10. No engine will be ruled out on account of an accident, but will be credited with all work done during the time of trial.

11. A detailed programme, with rules to be observed, will be furnished to competitors previous to the trial; and in this programme provision will also be made for the trial of competing portable and stationary fire-extinguishers.

12. The trials will be conducted under the supervision of a Committee of the Judges of Group XX., consisting of Messrs. Chas. T. Porter, Emil Brugsch, and Joseph Belknap, assisted by Mr. Wellington Lee, of New York.

A. T. GOSHORN, *Director-General*.

FRANCIS A. WALKER, *Chief of Bureau of Awards*.

[No. 229.]

RULES TO BE OBSERVED AT THE TRIAL OF STEAM FIRE-ENGINES, TO BE HELD ON THE GROUNDS OF THE INTERNATIONAL EXHIBITION, COMMENCING SEPTEMBER 4.

1st. The engines will take up positions on the 4th of September, at the dock, in front of the north central entrance of Machinery Hall, so that everything may be in readiness on the 5th. Engines are not to be removed from their positions until required for the street test, unless for some unforeseen cause.

2d. Two lines of leading-hose will be attached to each engine, the one through which the playing is done to be furnished by the exhibitor; the other, leading to the Judges' stand, to be furnished by the Judges, and to it are to be attached the water-pressure gauges.

3d. At least thirty-five feet of suction-pipe are to be used by each engine.

4th. The nozzle-pipes will all be secured to a frame, and will not need men to hold them.

5th. Wood and coal will be furnished by the Commission, but will be weighed and an account kept, and the facts so ascertained will be considered in making the general statement.

TRIAL NO. 1 is the first of which any record is to be made, and will commence on the 5th of September, at 10 A.M., and will be continued for at least one hour of continuous work.

a. The water in boiler to be cold.

b. The temperature to be ascertained and recorded.

c. Boilers filled to line agreed upon at the day of weighing.

d. Fires to be laid from wood and coal furnished by the Judges.

e. Largest size pro-rata nozzle to be used.

f. All to start fires at a given signal.

Frequent observations will be made of the pressure of steam and water as soon as indicated, and the facts will be duly recorded.

TRIAL NO. 2 will continue for one hour or more, at which the medium-sized nozzle will be used, and to follow No. 1 with as little delay as possible, without drawing the fires.

TRIAL NO. 3 will be for one hour or more, at which the small or pressure nozzle will be used. To follow Nos. 1 and 2 without drawing the fires.

TRIAL NO. 4 commences on the 6th of September at 3.20 o'clock P.M., and will be with large size nozzle, to be furnished by exhibitor, but of same diameter as large pro-rata nozzle used respectively at trial No. 1, and will be for distance and character of stream. Duration of trial, one or more hours. Boiler filled with cold water, etc., same as in trial No. 1.

TRIAL NO. 5 will be for one hour or more, and similar to No. 4, excepting in this case a medium-sized nozzle will be used. To follow No. 4 without drawing the fires.

TRIAL NO. 6 will be same as Nos. 4 and 5, excepting that in this case a small or pressure nozzle will be used. To follow No. 5 without drawing fires.

TRIALS NOS. 7, 8, AND 9 will begin on the 7th of September, at 10 o'clock A.M., and will be for vertical stream, and in other respects similar to Nos. 4, 5, and 6, the exhibitors selecting the nozzles, but conforming as nearly as practicable to the three sizes of pro-rata nozzles furnished by the Judges.

TRIAL NO. 10.—*a.* Will be for playing at the dock and running on the street, and will commence at 10 o'clock, with new-laid fire, etc., same as trial No. 1.

b. Each engine (except those run by hand) to be furnished with two horses selected by the exhibitors respectively.

c. The engines to carry coal necessary for one hour's consumption, and also all tools and twenty-five feet of suction-hose, and all the men that are required to work the engine at the dock.

d. The engines and loads so made up are to be weighed.

2. The engines will be started together, and run over a course of at least one mile, returning to the dock, where they are to be worked for at least half an hour from the time the first engine returns to the dock and commences playing, medium nozzles to be used by all the engines.

TRIAL NO. 11 will be in all respects similar to No. 10, except a new fire may or may not be laid.

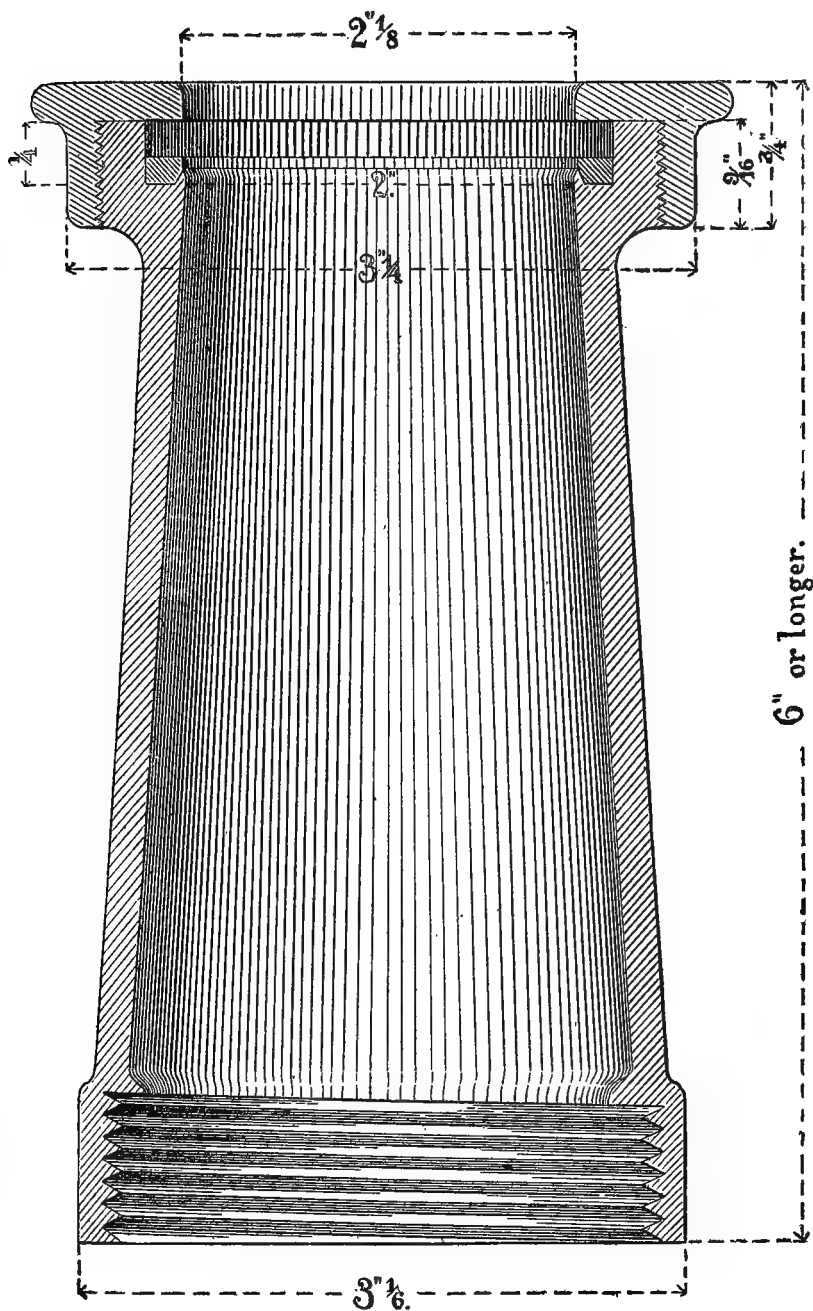
TRIAL NO. 12 will be similar to No. 11, but each engine will, if desired, take in a new supply of coal, and lay or not lay a new fire, as may be directed by the Judges.

TRIAL NO. 13 will be similar to No. 12, except that each exhibitor will use any nozzle he may desire, both as to diameter and form.

The Judges will measure the nozzles so chosen, and the results of play will be duly considered in making up the account.

A. T. GOSHORN, *Director-General*.

FRANCIS A. WALKER, *Chief of Bureau of Awards*.



NOZZLE-PIPE USED FOR THE STEAM FIRE-ENGINES.

RULES TO BE OBSERVED AT THE TRIAL OF CHEMICAL FIRE-ENGINES, TO BE HELD ON THE GROUNDS OF THE INTERNATIONAL EXHIBITION, COMMENCING SEPTEMBER 6.

TRIAL A, No. 1, will commence on the 6th of September, and all competing engines will take up positions at the dock, in front of the north central entrance of Machinery Hall, at 10 o'clock A.M.

a. Four charges of chemicals will be used by each engine, which will be weighed, and quantity of water ascertained for each charge.

b. To start at a given signal, with all valves closed, as if running on street.

c. Largest-sized pro-rata nozzle to be used.

d. Pressure and duration of stream to be noted, which will include observations as to breaks or stoppages of the stream (if any) while changing plug from one tank to another.

TRIAL A, No. 2, will follow trial No. 1 immediately, and will continue as long as one tank of each engine will give a stream under a pressure of five pounds per square inch. The medium-sized nozzle will be used.

TRIAL A, No. 3, will follow immediately, and be of the same nature as No. 2, except that the *smallest* pro-rata nozzle will be used.

TRIAL B, No. 1, will be for length of stream and completeness of chemical combination, but may be omitted if the above facts have been satisfactorily ascertained during the preceding trials.

TRIAL B, No. 2, will be for extinguishing fire in a building to be erected by the exhibitors, at the northeast side of the grounds, near the wind-mills. Each exhibitor will build such size and kind of house as he may judge best, and also fill the same to an extent and with such kind of inflammable material as he may choose, but a careful account will be kept of all such material used, either in the construction or filling.

The building will be fired at a signal, and the engines will commence their efforts to extinguish the flames at another signal agreed upon. All facts developed by burning and work to extinguish the fire will be carefully noted.

Should a considerable portion of the building and material remain unconsumed after the first firing, it will be repeated one or more times under the same rules as at first.

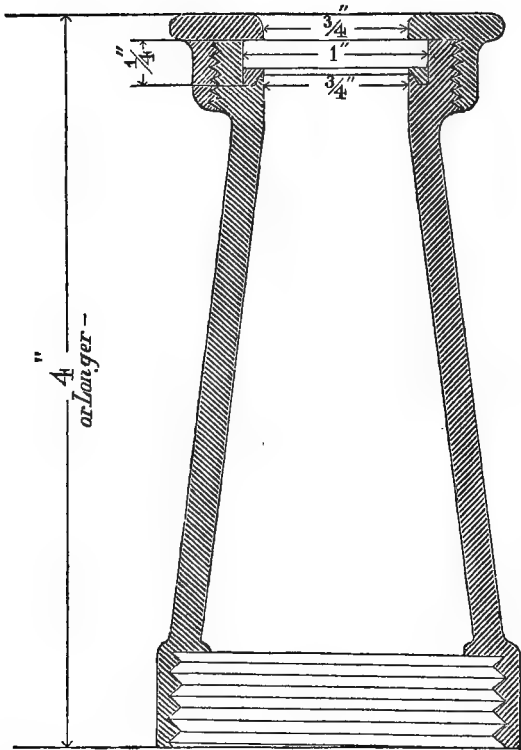
TRIAL C, No. 1, will be for playing at the dock and running on the street, and will take place on the 8th of September, and will be carried on in connection with the trial of steam fire-engines; and the chemical engines will be subject to the same general rules as to horses, and also being charged and equipped, ready for fire and street duty, etc., except that supplies will be carried for one-half hour, and will play at the dock, exhausting but two tanks through pro-rata nozzles.

The pressure, duration of stream, time of departure and arrival, and, as far as possible, all other facts developed, will be duly noted.

TRIALS C, Nos. 2 AND 3, will be of the same general nature in connection with the steamers, and may be repeated if the Judges think it desirable to do so.

a. Pressure-gauges will be tested by the Judges previous to the trials.

b. In trials for pressure or length of stream, equal lengths of hose will be used by all the engines respectively.



NOZZLE-PIPE USED FOR THE CHEMICAL FIRE-ENGINES.

EXHIBIT B.

TRIAL No. 1. LARGE PRO-RATA NOZZLE.

A RECORD OF TIME, AND WATER- AND STEAM-PRESSURES, FOR THE STEAM FIRE-ENGINES. COMMENCING AT 11.16 O'CLOCK A.M., SEPTEMBER 5, 1876.

TIME.	ENGINE 1. Diameter of Nozzle, 1.873".		ENGINE 2. Diameter of Nozzle, 1.596".		ENGINE 3. Diameter of Nozzle, 1.947".		ENGINE 4. Diameter of Nozzle, 1.938".		ENGINE 5. Diameter of Nozzle, 1.755".		ENGINE 6. Diameter of Nozzle, 1.326".		ENGINE 7. Diameter of Nozzle, 1.863".		ENGINE 8. Diameter of Nozzle, 1.636".		ENGINE 11. Diameter of Nozzle, 1.445".	
	Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.	
	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.
11.18		6						5										
11.19																		
11.20																		
11.22			10	11	12	11				7		5		6		15		5
11.23	35		40	40	40	40												
11.25	95		62	45	70	45												
11.26	110		80		80													
11.28	130	85	75	50	50	50	55											
11.30	140		70		90		85					40		100		75	110	95
11.31	141		82		90		100					39		100		85	110	
11.32	145		80	135	143	135	110					55		115		77	114	
11.34	143		84	139	139		98	50	100	110		63		121		83	110	
												70		130		95	115	

11.36	145	76	56	120	134	99	76	80	124	96	115	90
11.38	135	77		90	125	94	79	120	120	100	119	
11.40							90	135	135	40	105	
11.41						105						
11.42	145											
11.43											110	
11.44	150				135					90		
11.45	155	100			103	60	75	120	120	86	107	
11.47	143						65	137	137			
11.49	154	103			100	103	72	125	125	87	115	
11.50	158	110	60					130	130		109	
11.53						110	85	120	120	90	110	
11.54	156	110			125							95
11.55	150	110	64	110	110							
11.57	156	110		115	127		75	80				
11.58							75	110	110	90	111	
11.59	150			109	115				116		95	
12.00	146	88	65	120	119	70	85	75	114	95	110	75
12.01					110		85	115				
12.02	155						75			90		
12.03											90	
12.04	140	105		103	120							
12.05				103	120		75	100	100	93	120	
12.06							80					
12.07	156	111		111	120	100	70	100	100	90	120	
12.08							85	110	110		105	
Total.....	3333	454	1595	1693	2298	240	1489	280	2526	1497	2378	360
Average.....	138.875	75.667	83.947	95.471	92.2	48	79.4	56	105.25	83.166	108.091	72

TRIAL No. 3. SMALL PRO-RATA NOZZLE.

A RECORD OF TIME, AND WATER- AND STEAM-PRESSURES, FOR THE STEAM FIRE-ENGINES. COMMENCING AT 3.49 O'CLOCK P.M., SEPTEMBER 5, 1876.

TIME.	ENGINE 1. Diameter of Nozzle, 1.136".		ENGINE 2. Diameter of Nozzle, 0.896".		ENGINE 3. Diameter of Nozzle, 1.056".		ENGINE 4. Diameter of Nozzle, 1.051".		ENGINE 5. Diameter of Nozzle, 0.959".		ENGINE 6. Diameter of Nozzle, 0.726".		ENGINE 7. Diameter of Nozzle, 1.022".		ENGINE 8. Diameter of Nozzle, ———".		ENGINE 11. Diameter of Nozzle, 0.508".	
	Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.		Pressure in Pounds per Square Inch.	
	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.
3.48	84		140	81							160	103		115			175	115
3.49		91				80	85							115			220	
3.50			145								180		190				210	
3.51	230		155			190							250					
3.52	205																	
3.54						200					200		254				225	
3.55	245		145			125											225	
3.56																		
3.57	250		159			166					195		220					
3.58						135					200		230					
3.59	246		155			125					185		254				226	
4.00	240	95	139	77		75					151	80	185	120			224	115
4.01	246		164			185												
4.02	245										220		250				235	
4.03			164								205		240				215	
4.04	250		169			104					205							
4.05	239		164			125					209		250				230	
4.06	251		150														229	
4.07						137							250				235	

TRIAL No. 4. LARGE PRO-RATA NOZZLE.

A RECORD OF TIME AND WATER- AND STEAM-PRESSURES, FOR THE STEAM FIRE-ENGINES, COMMENCING AT 3:22 O'CLOCK P.M., SEPTEMBER 6, 1876.

TIME.	ENGINE 1. Diameter of Nozzle, 1.873".		ENGINE 2. Diameter of Nozzle, 1.596".		ENGINE 3. Diameter of Nozzle, 1.947".		ENGINE 4. Diameter of Nozzle, ———".		ENGINE 5. Diameter of Nozzle, ———".		ENGINE 6. Diameter of Nozzle, 1.326".		ENGINE 7. Diameter of Nozzle, 1.863".		ENGINE 8. Diameter of Nozzle, ———".		ENGINE 11. Diameter of Nozzle, 1.445".	
	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.	Water.	Steam.
3:23	66	.....	79	.....	69	.....	.....	.....	.....	.....	64	.....	42	.....	.....	.....	83	.....
3:25	64	.....	79	.....	83	127	.....	.....	.....	.....	42	.....	50	69	.....	.....	79	.....
3:26	82	70	80	55	75	.....	.....	.....	.....	.....	41	.....	61	.....	.....	.....	85	70
3:27	80	.....	66	.....	80	.....	.....	.....	.....	.....	53	87	79	.....	.....	.....	75	.....
3:28	89	.....	71	.....	66	.....	.....	.....	.....	.....	51	.....	90	.....	.....	.....	84	.....
3:29	81	.....	70	.....	56	.....	.....	.....	.....	.....	53	.....	120	.....	.....	.....	75	.....
3:30	79	.....	65	.....	66	.....	.....	.....	.....	.....	54	.....	121	.....	.....	.....	94	.....
3:31	89	.....	75	.....	60	.....	.....	.....	.....	.....	44	.....	115	.....	.....	.....	103	.....
3:32	85	.....	81	.....	58	.....	.....	.....	.....	.....	57	.....	118	.....	.....	.....	102	.....
3:33	84	.....	84	.....	65	.....	.....	.....	.....	.....	54	.....	119	.....	.....	.....	101	.....
3:34	86	.....	82	.....	51	.....	.....	.....	.....	.....	55	.....	119	.....	.....	.....	100	.....
3:35	86	73	81	.....	60	126	.....	.....	.....	.....	55	.....	107	100	.....	.....	96	.....
3:36	.....	.....	60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	100	.....
3:37	89	.....	79	.....	63	.....	.....	.....	.....	.....	54	94	128	.....	.....	.....	103	.....
3:38	84	.....	79	.....	62	.....	.....	.....	.....	.....	53	.....	115	.....	.....	.....	100	.....
3:39	85	.....	75	.....	60	.....	.....	.....	.....	.....	56	.....	100	.....	.....	.....	100	.....
3:40	81	.....	81	.....	59	.....	.....	.....	.....	.....	54	.....	126	.....	.....	.....	90	.....
3:41	89	.....	80	.....	51	.....	.....	.....	.....	.....	54	.....	110	.....	.....	.....	96	.....
3:42	93	.....	78	.....	65	.....	.....	.....	.....	.....	54	.....	115	.....	.....	.....	94	.....
3:44	89	.....	76	.....	70	.....	.....	.....	.....	.....	54	.....	101	.....	.....	.....	102	.....
3:45	91	.....	62	.....	64	.....	.....	.....	.....	.....	54	.....	120	.....	.....	.....	105	.....

TRIAL No. 5. MEDIUM PRO-RATA NOZZLE.

A RECORD OF TIME, AND WATER- AND STEAM-PRESSURES, FOR THE STEAM FIRE-ENGINES. COMMENCING AT 2.08 O'CLOCK P.M., SEPTEMBER 6, 1876.

TIME.	ENGINE 1. Diameter of Nozzle, 1.383".		ENGINE 2. Diameter of Nozzle, 1.135".		ENGINE 3. Diameter of Nozzle, 1.422".		ENGINE 4. Diameter of Nozzle, ———".		ENGINE 5. Diameter of Nozzle, ———".		ENGINE 6. Diameter of Nozzle, 0.976".		ENGINE 7. Diameter of Nozzle, 1.364".		ENGINE 8. Diameter of Nozzle, ———".		ENGINE 11. Diameter of Nozzle, 1.012".	
	Pressure in Pounds per Square Inch.	Water.	Pressure in Pounds per Square Inch.	Steam.	Pressure in Pounds per Square Inch.	Water.	Pressure in Pounds per Square Inch.	Steam.	Pressure in Pounds per Square Inch.	Water.	Pressure in Pounds per Square Inch.	Steam.	Pressure in Pounds per Square Inch.	Water.	Pressure in Pounds per Square Inch.	Water.	Pressure in Pounds per Square Inch.	Steam.
2.08	145	130	.....	110	.....	.....	.....	.....	103	.....	.....	159	.....	.....	.....	133	.....
2.09	77	160	111	.....	119	130	.....	.....	.....	99	85	.....	165	110	.....	.....	135	85
2.10	148	118	72	129	.....	.....	.....	.....	98	.....	.....	157	.....	.....	.....	118	.....
2.11	159	123	.....	120	.....	.....	.....	.....	97	.....	.....	165	.....	.....	.....	130	.....
2.12	165	116	.....	115	.....	.....	.....	.....	100	.....	.....	168	.....	.....	.....	140	.....
2.13	176	115	.....	114	.....	.....	.....	.....	96	.....	.....	155	.....	.....	.....	135	.....
2.14	175	122	.....	125	.....	.....	.....	.....	93	.....	.....	159	.....	.....	.....	125	.....
2.15	176	120	.....	120	.....	.....	.....	.....	80	.....	.....	157	.....	.....	.....	130	.....
2.16	170	125	.....	124	.....	.....	.....	.....	87	.....	.....	163	.....	.....	.....	135	.....
2.17	174	122	.....	120	.....	.....	.....	.....	97	.....	.....	163	.....	.....	.....	135	.....
2.18	173	125	.....	139	.....	.....	.....	.....	101	.....	.....	153	.....	.....	.....	133	.....
2.19	171	127	.....	135	.....	.....	.....	.....	96	.....	.....	159	.....	.....	.....	136	.....
2.20	177	127	.....	124	125	.....	.....	.....	102	.....	.....	163	115	.....	.....	133	.....
2.21	95	.....	68	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2.22	178	120	.....	127	.....	.....	.....	.....	99	83	.....	172	.....	.....	.....	135	90
2.23	174	125	.....	122	.....	.....	.....	.....	92	.....	.....	167	.....	.....	.....	120	.....
2.24	175	126	.....	136	.....	.....	.....	.....	97	.....	.....	156	.....	.....	.....	125	.....
2.25	178	120	.....	131	.....	.....	.....	.....	97	.....	.....	170	.....	.....	.....	141	.....
2.26	174	117	.....	123	.....	.....	.....	.....	96	.....	.....	167	.....	.....	.....	140	.....
2.28	175	124	.....	127	.....	.....	.....	.....	95	.....	.....	153	.....	.....	.....	137	.....
2.29	166	122	.....	135	.....	.....	.....	.....	94	.....	.....	170	.....	.....	.....	140	.....
2.30	170	127	.....	124	127	.....	.....	.....	100	.....	.....	164	115	.....	.....	147	.....

2.31	173	97	129	79	127	130	103	90	106	100	141	100
2.32	172	126	124	124	114	101	101	170	170	140	140	140
2.33	171	130	130	130	111	95	95	170	170	143	143	143
2.34	170	130	130	130	105	101	101	180	180	132	132	132
2.35	177	116	116	116	110	104	104	160	160	145	145	145
2.36	174	122	122	122	110	102	102	160	160	151	151	151
2.37	174	117	117	117	120	95	95	175	175	139	139	139
2.38	171	93	102	65	121	121	121	85	163	140	140	95
2.41	170	116	116	116	122	100	100	164	164	144	144	144
2.43	175	117	117	117	116	101	101	155	155	122	122	122
2.45	174	116	116	116	112	105	105	170	170	131	131	131
2.47	175	109	109	109	98	100	100	166	166	135	135	135
2.49	177	126	126	126	103	107	107	163	163	139	139	139
2.50	174	92	126	74	103	130	130	91	160	100	100	100
2.51	173	129	129	129	99	109	109	119	119	136	136	136
2.52	171	119	119	119	90	99	99	134	134	140	140	140
2.54	169	123	123	123	87	106	106	140	140	143	143	143
2.55	171	119	119	119	105	110	110	139	139	136	136	136
2.57	174	116	116	116	90	106	106	140	140	144	144	144
2.58	168	130	130	130	90	106	106	85	140	133	133	133
3.00	174	119	119	119	105	105	105	140	140	145	145	145
3.01	174	120	120	120	115	100	100	120	120	135	135	135
3.02	169	125	125	125	114	101	101	161	161	140	140	140
3.03	175	117	117	117	83	105	105	105	105	145	145	145
3.05	169	114	114	114	98	106	106	85	163	151	151	151
3.06	173	119	119	119	108	105	105	150	150	140	140	140
3.07	179	126	126	126	109	109	109	130	130	153	153	153
3.08	173	93	126	75	120	115	115	164	164	150	150	150
3.09	173	75	126	75	120	115	115	84	164	150	150	150
3.10	173	75	126	75	120	115	115	84	164	150	150	150
3.11	173	75	126	75	120	115	115	84	164	150	150	150
Total.....	8223	725	5807	582	5510	1156	4816	688	7573	893	6596	770
Average.....	171.312	90.605	120.979	72.75	114.792	128.444	100.33	86.00	157.77	111.625	137.417	96.25

TRIAL No. 7. LARGE PRO-RATA NOZZLE.

A RECORD OF TIME, AND WATER- AND STEAM-PRESSURES, FOR THE STEAM FIRE-ENGINES. COMMENCING AT 10.13½ O'CLOCK A.M., SEPTEMBER 7, 1876.

TIME.	ENGINE 1. Diameter of Nozzle, 1.873".		ENGINE 2. Diameter of Nozzle, 1.596".		ENGINE 3. Diameter of Nozzle, 1.947".		ENGINE 4. Diameter of Nozzle, 1.938".		ENGINE 5. Diameter of Nozzle, 1.755".		ENGINE 6. Diameter of Nozzle, 1.326".		ENGINE 7. Diameter of Nozzle, 1.865".		ENGINE 8. Diameter of Nozzle, —".		ENGINE 11. Diameter of Nozzle, 1.445".	
	Pressure in Pounds per Square Inch.	Water.	Pressure in Pounds per Square Inch.	Steam.	Pressure in Pounds per Square Inch.	Water.	Pressure in Pounds per Square Inch.	Steam.	Pressure in Pounds per Square Inch.	Water.	Pressure in Pounds per Square Inch.	Steam.	Pressure in Pounds per Square Inch.	Water.	Pressure in Pounds per Square Inch.	Water.	Pressure in Pounds per Square Inch.	Steam.
10.18	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.19	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.20	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.21	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.22	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.23	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.24	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.25	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.26	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.27	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.28	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.29	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.30	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.31	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.32	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.33	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.34	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.35	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.36	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.37	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.38	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.39	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.40	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.41	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.42	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.43	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.44	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.45	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.46	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70
10.47	15	6	25	10	22	0	25	5	14	21	8	5	24	10	10	10	100	70

2.07	211	92	130	72	120	130	190	38	145	100	215	111	150	120
2.08	210	135	135	123	111	183	85	38	165	200	200	111	149	1037
2.10	215	139	123	125	125	200	200	38	153	185	185	111	150	1037
2.13	211	131	121	124	124	156	211	36	165	180	180	111	150	1037
2.15	205	125	125	125	125	201	201	36	157	90	185	111	145	1037
2.18	205	125	125	125	125	201	201	36	157	90	185	111	145	1037
2.19	215	97	136	71	120	215	215	31	130	190	190	110	137	1037
2.20	215	136	136	71	120	215	215	31	130	190	190	110	137	1037
2.21	210	131	131	123	123	210	210	40	146	200	200	110	125	1037
2.22	210	131	131	123	123	210	210	40	146	200	200	110	125	1037
2.23	205	131	131	101	101	155	155	45	160	175	175	110	120	1037
2.25	210	125	125	93	93	201	201	41	157	215	215	110	139	1037
2.27	210	125	125	93	93	201	201	41	157	215	215	110	139	1037
2.28	210	125	125	93	93	201	201	41	157	215	215	110	139	1037
2.29	200	94	130	62	120	186	186	34	145	90	208	120	136	1037
2.30	200	94	130	62	120	186	186	34	145	90	208	120	136	1037
2.33	218	138	138	81	120	177	177	38	150	170	170	110	160	1037
2.35	215	139	139	38	130	175	175	30	155	190	190	110	160	1037
2.37	205	135	135	51	190	190	190	31	156	181	181	110	160	1037
2.40	211	97	126	60	56	165	165	31	160	95	199	116	104	1037
2.41	211	97	126	60	56	165	165	31	160	95	199	116	104	1037
2.42	204	139	139	65	130	167	167	37	150	210	210	116	160	1037
2.43	205	130	130	70	120	190	190	38	160	220	220	116	160	1037
2.45	205	130	130	70	120	190	190	38	160	220	220	116	160	1037
2.48	199	134	134	100	100	160	160	20	135	215	215	116	160	1037
2.50	190	90	140	69	118	130	130	19	145	100	221	120	165	1037
2.51	190	90	140	69	118	130	130	19	145	100	221	120	165	1037
2.52	199	131	131	123	123	179	179	16	159	201	201	120	162	1037
2.53	198	131	131	91	130	190	190	16	143	220	220	120	162	1037
2.54	201	136	136	110	110	190	190	15	130	179	179	120	160	1037
2.55	195	135	135	125	125	191	191	14	135	200	200	120	160	1037
2.56	196	140	140	70	120	195	195	15	141	99	207	120	160	1037
2.57	201	86	137	73	129	190	190	12	145	99	207	120	160	1037
2.58	186	138	138	110	110	198	198	18	155	185	185	120	155	1037
2.59	206	135	135	124	124	187	187	15	152	192	192	120	155	1037
3.00	201	135	135	104	104	176	176	18	139	208	208	120	155	1037
				110	110	166	166	19	147	191	191	120	155	1037
Total.....	10,887	844	6877	615	5846	9042	677	3071	7787	869	10,558	1028	7651	1037
Average.....	205.415	93.778	132.250	68.333	110.302	170.604	75.222	57.943	146.924	96.555	199.207	114.222	147.134	115.222

2.30	0	82	128	75	140	140	140
2.31	118				170		
2.32	133						
2.33	133						
2.34	180	90					
2.35	182						
2.36	171		130		169		
2.37	173		129		129		
2.38	170		131		154		
2.39	180		134		160		
2.40	186		130		175		
2.41	186	90	123	75	163	110	
2.42	181		116		160		
2.43	194		126		153		
2.45	160	76	153	85	146		
2.48	179		129		153	119	
2.49	176		126		141		
2.50	182	92	134	70	144		
2.52	170		138		145	102	
2.53	183		132		146		
2.55	180	90	121	60	160		
2.57	179		120		154	113	
2.58	176		139		150		
3.00	176	93	140		141	105	
3.01	173		134	77	120		
3.03	172		123		155		
3.05	175	87	135	70	153	114	
3.07	181		126		155		
3.09	152		98				
3.24	153	82	104	60	160	119	
3.25	146		125		166		
3.26	160		127		167		
3.27	158		130		145		
3.28	163		126		170		
3.30	169		146		155		
3.32	166		122		154		
3.34	175	89	121	62	162		
3.35	159		126		154	116	
3.36	170		143		161		
3.37	166		130		165		
3.39	176		96		158		
3.44					144		
3.44							
Total.....	6638	871	7968	1037	10,617	1804	
Average.....	96.203	87.1	118.925	69.133	156.13	112.75	

EXHIBIT C.

TABLE A.

SHOWING THE VARIOUS WEIGHTS OF THE DIFFERENT STEAM FIRE-ENGINES ENTERED FOR THE TRIAL, AND ALSO THE DIAMETERS OF THE PRO-RATA NOZZLES USED.

NO. OF ENGINE.	EXHIBITOR.	LIGHT WEIGHT WITHOUT WATER. POUNDS.	WEIGHT WITH WATER. POUNDS.	WEIGHT, LOADED READY FOR DUTY, AND FOUR MEN. POUNDS.	PRESSURE TO WHICH TESTED. LBS. ON SQUARE INCH.	DIAMETER SMALL SIZE PRO-RATA NOZZLE. INCHES.	DIAMETER MEDIUM SIZE PRO-RATA NOZZLE. INCHES.	DIAMETER LARGE SIZE PRO-RATA NOZZLE. INCHES.
1	Silsby Manufacturing Co.....	6596	7045	8175	200	1.136	1.383	1.873
2	Silsby Manufacturing Co.....	4795	5140	.....	200	0.876	1.135	1.596
3	B. S. Nichols & Co.....	7122	7323	.....	255	1.056	1.422	1.947
4	La France Manufacturing Co.....	7051	7355	8310	200	1.051	1.416	1.938
5	John D. Ronald.....	5812	6022	.....	240	0.959	1.270	1.755
6	Clapp & Jones.....	3310	3505	.....	240	0.726	0.976	1.326
7	Clapp & Jones.....	6503	6825	7847	240	1.012	1.364	1.863
8	L. Button & Son.....	5035	5225	.....	240	0.888	1.195	1.636
9	Amoskeag Manufacturing Co.....	7522	8920	.....	230	1.085	1.461	2.000
10	Amoskeag Manufacturing Co.....	6105	6264	.....	.....	0.978	1.317	1.802
11	Clapp & Jones.....	3925	4098	.....	240	0.408	1.012	1.445

TABLE B.

GENERAL AVERAGES OF ALL THE ENGINES.

NO. OF ENGINE.	AVERAGE WATER-PRESSURE. LBS. ON SQUARE INCH.	AVERAGE WATER-PRESSURE AS CORRECTED. LBS. ON SQUARE INCH.	AVERAGE STEAM-PRESSURE. LBS. ON SQUARE INCH.	AVERAGE HEIGHT THROWN. FEET.	DISTANCE. FEET.	AVERAGE DIAMETER PRO-RATA NOZZLES. INCHES.	AGGREGATE CONSTRUCTION MARKS.	POUNDS OF COAL.	POUNDS OF WOOD.	TOTAL OIL AC-COUNT.	TOTAL TALLOW AC-COUNT. POUNDS.
1	144.6454	139.6454	82.9980	174.667	203.401	1.4559	48.941	10,880	275¾	} 5 galls	.....
2	108.5099	108.5099	64.8875	.....	187.361	1.2023	46.747	4,212	193		.....
3	78.0727	82.0727	109.7105	.....	202.880	1.4697	48.989	6,581	194	1 quart.	.....
4	78.8623	78.8623	62.8101	.....	47.666	1.4631	47.876	8,054	240¾	2½ galls	.....
5	64.1126	64.1126	67.6807	.....	27.222	1.3222	47.961	4,880½	211¾	1½ pts.	.....
6	119.0355	119.0350	84.9372	.....	182.361	1.0093	49.994	2,686	173½	¾ gall.	1¼
7	157.0818	157.0818	99.1347	202.33	215.2376	1.4081	51.337	8,715	280¾	¾ "	1¼
8	8.3166	8.3166	65.60000	.....	.....	1.2352	46.694	287½	65	½ pt.	.....
9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	145.4572	145.4572	100.6674	192.33	160.361	0.955	50.989	4,099	173¾	¾ gall.	1¼

TABLE C.

COMPARISON OF THE GENERAL AVERAGE OF CLAPP & JONES' ENGINES WITH SILSBY'S ENGINES—AS THE RECORD WAS MADE.

NO. OF ENGINE.	AVERAGE WATER-PRESSURE, LBS. ON SQUARE INCH.	AVERAGE WATER-PRESSURE AS CORRECTED, LBS. ON SQUARE INCH.	AVERAGE STEAM-PRESSURE, LBS. ON SQUARE INCH.	AVERAGE HEIGHT THROWN, FEET.	DISTANCE, FEET.	AVERAGE DIAMETER PRO-RATA NOZZLES, INCHES.	AGGREGATE CONSTRUCTION MARKS.	POUNDS OF COAL.	POUNDS OF WOOD.	TOTAL OIL ACCOUNT, GALLONS.	TOTAL TALLOW ACCOUNT, POUNDS.
1 & 2	126.578	124.078	73.9427	.....	195.381	1.3291	47.844	7,546	234.375	2½	0
7 & 11	151.269	151.269	99.9010	.....	187.799	1.1815	51.163	6,407	227.50	0.583	1.25
6, 7 & 11	140.525	140.525	94.9131	.....	185.986	1.1241	50.773	5,166.60	209.166	0.500	1.25

TABLE D.

TRIAL No. 10, SHOWING TIME OF STARTING AND RETURN OF ENGINES, AND TIME OF GETTING TO WORK AT DOCK.

NO. OF ENGINE.	TIME OF STARTING.	TIME OF RETURN.	TIME OF GETTING TO WORK AT DOCK.	MINUTES MAKING THE RUN.	MINUTES GETTING TO WORK.	MINUTES CHEMICAL ENGINE AHEAD.	MINUTES NO. 7 AHEAD OF NOS. 1 AND 4.
1	2.09¾	2.30	2.31¾	20¾	1¾	5½	1¾
4	1.34	1.57	2.00	23	3	8½	4½
7	1.33½	1.52	1.53¾	18½	1½	3¾	.....
2 Chemical.	1.33¾	1.48½	1.49¾	14¾	¾	.....	.....

TABLE E.

AGGREGATE AREA OF THE FOUR AXLE JOURNALS OF THE DIFFERENT ENGINES, AND THE PRO-RATA STRENGTH OF EACH ENGINE AS COMPARED WITH No. 7's LIGHT WEIGHT.

NO. OF ENGINE.	AGGREGATE AREA OF THE FOUR BEARINGS, SQUARE INCHES.	WEIGHT OF ENGINE, POUNDS.	POUNDS HEAVIER, PRO-RATA.	POUNDS LIGHTER, PRO-RATA.	REMARKS.
1	25.912	6596	635.425	Standard.
2	16.516	4795	995.798	.....
3	31.384	7122	.....	97.333
4	28.270	7064	561.000	.....
5	21.672	5812	826.746	.....
6	15.904	3310	.....	348.420
7	28.270	6503	000.000	000.000	
8	21.276	5035	140.842	.....
9	23.954	7522	2011.817	.....
10	23.476	6105	694.78	.....
11	15.904	3925	266.579	.....

TABLE F.

DIMENSIONS OF THE DIFFERENT BOILERS, AND STEAM- AND WATER-CYLINDERS.

No. OF ENGINE.	DIAMETER AND HEIGHT OF BOILER, INCHES.	HEATING SURFACE IN SQUARE FEET.	DIAMETER OF STEAM-CYLINDER, INCHES.	STROKE OF STEAM-PISTON, INCHES.	DIAMETER OF WATER-CYLINDER, INCHES.	STROKE OF WATER-PISTON, INCHES.	RATIO OF CAPACITIES OF WATER AND STEAM CYL'DERS.		REMARKS.
							Water.	Steam.	
1	40 X 60	330	{ 13.50 6.25 }	-----	{ 8.38 5.25 }	-----	-----	-----	Rotary.
2	36 X 56	197	-----	-----	-----	-----	-----	-----	"
3	40 X 60	251	9	7	6	7	1	2.25	Rotary.
4	32 X 56	265	-----	-----	-----	-----	-----	-----	"
5	40 X 56	-----	7.75	9	4.33	9	1	3.203	Rotary.
6	38 X 52	123	7	7	4.25	7	1	2.714	"
7	38 X 58	248	8	8	4.78	8	1	2.990	Double.
8	34½ X 60	190	12	4½	{ 6¾ 4½ }	{ 4½ 4½ }	{ 1 1 }	{ 2.250 3.163 }	Double.
9	31¾ X 64	175	7½	8	4½	8	1	2.871	Propeller.
10	30½ X 61	151	6½	8	4¾	8	1	2.615	Double.
11	32 X 52	147	8	8	4¾	8	1	2.693	"

TABLE G.

AVERAGE LENGTH OF STREAM THROWN VERTICALLY AND HORIZONTALLY, AND AVERAGE PRESSURES OF WATER AND STEAM MAINTAINED BY SILSBY ENGINE, No. 1, DURING TRIALS OF SEPTEMBER 5, 6, 7, 8, 1876.

No. OF TRIAL.	AVERAGE HEIGHT OF VERTICAL STREAM, FEET.	DISTANCE THROWN, HORIZONTAL, FEET.	AVERAGE WATER-PRESSURE, POUNDS PER SQUARE INCH.	AVERAGE STEAM-PRESSURE, POUNDS PER SQUARE INCH.	DIAMETER OF PRO-RATA NOZZLES, INCHES.	REMARKS.
1	-----	-----	138.875	75.667	1.873	Owing to bad weather, the observations of length of stream could not be satisfactorily made. Five gallons of oil for Nos. 1 and 2.
2	-----	-----	188.950	91.000	1.383	
3	-----	-----	238.054	96.143	1.136	
4	140	178.333	83.220	70.500	1.873	
5	219	236.870	171.312	90.625	1.383	
6	165	195.000	79.074	70.000	1.136	
7	-----	-----	80.653	63.667	1.873	
8	-----	-----	164.098	91.500	1.383	
9	-----	-----	205.415	93.778	1.136	
10	-----	-----	96.203	87.100	1.383	
.....	524	610.203	1446.454	829.98	14.559	

Average water-pressure..... 139.6454

Average steam-pressure..... 82.998

Average height thrown..... 174.667

Distance..... 203.401

Diameter (average) pro-rata nozzles... 1.4559

Aggregate construction marks..... 48.941

Pounds of coal..... 10,880

Pounds of wood..... 275.75

Fifty pounds are deducted from the average water-pressure of trial No. 1, on account of stoppage in discharge-hose..... 1446.454

50
1396.454

TABLE H.

AVERAGE LENGTH OF STREAM THROWN VERTICALLY AND HORIZONTALLY, AND AVERAGE PRESSURES OF WATER AND STEAM MAINTAINED BY SILSBY ENGINE, No. 2, DURING TRIALS OF SEPTEMBER 5, 6, 7, 8, 1876.

NO. OF TRIAL.	DISTANCE THROWN, HORIZONTAL. FEET.	AVERAGE WATER-PRESSURE. POUNDS PER SQUARE INCH.	AVERAGE STEAM-PRESSURE. POUNDS PER SQUARE INCH.	DIAMETER OF PRO- RATA NOZZLES. INCHES.	REMARKS.
1	83.947	52.000	1.596	Owing to bad weather, the observations of length of stream could not be satisfactorily made.
2	.....	123.816	76.000	1.135
3	.....	156.909	82.143	0.876
4	200.000	70.226	56.333	1.596	
5	220.833	120.979	72.750	1.135	
6	141.250	135.319	70.125	0.876	
7	.....	59.061	46.800	1.596
8	.....	94.082	59.500	1.135
9	.....	132.250	68.333	0.876
10	.....	.....	.....	.....
.....	562.083	976.589	583.984	10.821	Hand-engine—not entered.

Average water-pressure..... 108.5099
 Average steam-pressure..... 64.8875
 Distance..... 187.361
 Average diameter pro-rata nozzles..... 1.2023

Aggregate construction marks..... 46.747
 Pounds of coal..... 4212
 Pounds of wood..... 193

TABLE I.

AVERAGE LENGTH OF STREAM THROWN VERTICALLY AND HORIZONTALLY, AND AVERAGE PRESSURES OF WATER AND STEAM MAINTAINED BY NICHOLS ENGINE, No. 3, DURING TRIALS OF SEPTEMBER 5, 6, 7, 8, 1876.

NO. OF TRIAL.	DISTANCE THROWN, HORIZONTAL. FEET.	AVERAGE WATER-PRESSURE. POUNDS PER SQUARE INCH.	AVERAGE STEAM-PRESSURE. POUNDS PER SQUARE INCH.	DIAMETER OF PRO- RATA NOZZLES. INCHES.	REMARKS.
1	95.471	92.200	1.947	One quart of oil. Owing to bad weather, the observations of length of stream could not be satisfactorily made.
2	.....	146.625	119.571	1.422
3	.....	000.000	.....	1.056
4	220.000	54.780	128.333	1.947	
5	237.667	114.792	128.444	1.422	
6	151.000	153.851	97.222	1.056	
7	.....	41.021	70.200	1.947
8	.....	61.885	119.714	1.422
9	.....	110.302	122.000	1.056
10	.....	000.000	.....	1.422
.....	608.667	780.727	877.684	14.697	

Average water-pressure..... 82.0727
 Average steam-pressure..... 109.7105
 Distance..... 202.889
 Average diameter of pro-rata nozzles..... 1.4697

Aggregate construction marks..... 48.989
 Pounds of coal..... 6581
 Pounds of wood..... 194

An allowance of forty pounds is made in the average water-pressure of trial No. 8, for the stoppage of the suction by grass.....

780.727
 40
 820.727

TABLE J.

AVERAGE LENGTH OF STREAM THROWN VERTICALLY AND HORIZONTALLY, AND AVERAGE PRESSURES OF WATER AND STEAM MAINTAINED BY LA FRANCE ENGINE, No. 4, DURING TRIALS OF SEPTEMBER 5, 6, 7, 8, 1876.

NO. OF TRIAL.	DISTANCE THROWN, HORIZONTAL. FEET.	AVERAGE WATER-PRESSURE. POUNDS PER SQUARE INCH.	AVERAGE STEAM-PRESSURE. POUNDS PER SQUARE INCH.	DIAMETER OF PRO- RATA NOZZLES. INCHES.	REMARKS.
1	104.445	48.000	1.938	Two and one-half gallons of oil. Owing to bad weather, the observations of length of stream could not be satisfactorily made.
2	.....	165.481	81.857	1.416
3	.....	000.000	.....	1.051
4	000.000	000.000	.....	1.938
5	000.000	000.000	.....	1.416
6	143.000	66.312	51.667	1.051	
7	.....	35.250	46.667	1.938
8	.....	127.606	67.125	1.416
9	.....	170.604	75.222	1.051
10	.....	118.925	69.133	1.416
.....	143.000	788.623	439.671	14.631	

Average water-pressure..... 78.8623
 Average steam-pressure..... 62.8101
 Distance..... 47.666
 Average diameter of pro-rata nozzles... 1.4631

Aggregate construction marks..... 47.876
 Pounds of coal..... 8054
 Pounds of wood..... 240.25

TABLE K.

AVERAGE LENGTH OF STREAM THROWN VERTICALLY AND HORIZONTALLY, AND AVERAGE PRESSURES OF WATER AND STEAM MAINTAINED BY RONALD ENGINE, No. 5, DURING TRIALS OF SEPTEMBER 5, 6, 7, 8, 1876.

NO. OF TRIAL.	DISTANCE THROWN, HORIZONTAL. FEET.	AVERAGE WATER-PRESSURE. POUNDS PER SQUARE INCH.	AVERAGE STEAM-PRESSURE. POUNDS PER SQUARE INCH.	DIAMETER OF PRO- RATA NOZZLES. INCHES.	REMARKS.
1	85.471	79.400	1.755	One and one-half pints of oil. Owing to bad weather, the observations of length of stream could not be satisfactorily made.
2	.....	152.375	92.287	1.270
3	.....	94.694	40.142	0.959
4	000.000	000.000	.....	1.755
5	000.000	000.000	.....	1.270
6	81.666	29.412	53.200	0.959	
7	.....	97.100	55.333	1.755
8	.....	124.131	106.625	1.270
9	.....	57.943	46.778	0.959
10	.....	000.000	.....	1.270
.....	81.666	641.126	473.765	13.222	

Average water-pressure..... 64.1126
 Average steam-pressure..... 67.6807
 Distance..... 27.222
 Average diameter pro-rata nozzles..... 1.3222

Aggregate construction marks..... 47.961
 Pounds of coal..... 4889.5
 Pounds of wood..... 211.25

TABLE L.

AVERAGE LENGTH OF STREAM THROWN VERTICALLY AND HORIZONTALLY, AND AVERAGE PRESSURES OF WATER AND STEAM MAINTAINED BY CLAPP & JONES ENGINE, No. 6, DURING TRIALS OF SEPTEMBER 5, 6, 7, 8, 1876.

NO. OF TRIAL.	DISTANCE THROWN, HORIZONTAL. FEET.	AVERAGE WATER-PRESSURE. POUNDS PER SQUARE INCH.	AVERAGE STEAM-PRESSURE. POUNDS PER SQUARE INCH.	DIAMETER OF PRO- RATA NOZZLES. INCHES.	REMARKS.
1	70.905	56.000	1.326	One-third gallon of oil. One and one-fourth pounds of tallow. Owing to bad weather, ob- servations of length of stream could not be satisfactorily made.
2	.....	145.484	88.857	0.976
3	.....	197.028	93.857	0.726
4	208.333	54.180	91.833	1.326	
5	190.000	100.333	86.000	0.976	
6	148.750	184.413	96.250	0.726	
7	.....	55.479	63.833	1.326
8	.....	116.574	91.250	0.976
9	.....	146.924	96.555	0.726
10	.....	.....	.....	.....
.....	547.083	1071.320	764.435	9.084	Hand-engine—not entered.

Average water-pressure..... 119.035
 Average steam-pressure..... 84.9372
 Distance..... 182.361
 Average diameter pro-rata nozzles..... 1.0093

Aggregate construction marks..... 49.994
 Pounds of coal..... 2686
 Pounds of wood..... 173.5

TABLE M.

AVERAGE LENGTH OF STREAM THROWN VERTICALLY AND HORIZONTALLY, AND AVERAGE PRESSURES OF WATER AND STEAM MAINTAINED BY CLAPP & JONES ENGINE, No. 11, DURING TRIALS OF SEPTEMBER 5, 6, 7, 8, 1876.

NO. OF TRIAL.	AVERAGE HEIGHT OF VERTICAL STREAM. FEET.	DISTANCE THROWN, HORIZONTAL. FEET.	AVERAGE WATER-PRESSURE. POUNDS PER SQUARE INCH.	AVERAGE STEAM-PRESSURE. POUNDS PER SQUARE INCH.	PRO-RATA NOZZLES, AVERAGE PRESSURE.	REMARKS.
1	108.091	72.000	1.445	One-half gallon of oil. One and one-fourth pounds of tallow. Owing to bad weather, ob- servations of length of stream could not be satisfactorily made.
2	.....	.....	177.975	115.714	1.012
3	.....	.....	224.868	118.571	0.408
4	188	105.416	96.040	94.333	1.445	
5	200	181.667	137.417	96.250	1.012	
6	189	194.000	188.630	105.625	0.408	
7	.....	.....	96.042	79.167	1.445
8	.....	.....	132.918	109.125	1.012
9	.....	.....	147.134	115.222	0.408
10	.....	.....	.....	.....	.....
.....	577	481.083	1309.115	906.007	8.595	Hand-engine—not entered.

Average water-pressure..... 145.4572
 Average steam-pressure..... 100.6674
 Average height thrown..... 192.33
 Distance..... 160.361

Average diameter pro-rata nozzles..... 0.955
 Aggregate construction marks..... 50.989
 Pounds of coal..... 4099
 Pounds of wood..... 173.25

TABLE N.

AVERAGE LENGTH OF STREAM THROWN VERTICALLY AND HORIZONTALLY, AND AVERAGE PRESSURES OF WATER AND STEAM MAINTAINED BY CLAPP & JONES ENGINE, No. 7, DURING TRIALS OF SEPTEMBER 5, 6, 7, 8, 1876.

NO. OF TRIAL.	AVERAGE HEIGHT OF VERTICAL STREAM. FEET.	DISTANCE THROWN, HORIZONTAL. FEET.	AVERAGE WATER-PRESSURE. POUNDS PER SQUARE INCH.	AVERAGE STEAM-PRESSURE. POUNDS PER SQUARE INCH.	DIAMETER OF PRO-RATA NOZZLES. INCHES.	REMARKS.
1	105.250	75.333	1.863	Two-thirds of a gallon of oil. One and one-fourth pounds of tallow. Owing to bad weather, observations of length of stream could not be satisfactorily made.
2	.....	.....	186.786	108.857	1.364
3	.....	.....	226.270	108.143	1.012
4	199	216.785	103.220	92.167	1.863	
5	217	235.000	157.771	111.625	1.364	
6	191	193.928	184.044	97.500	1.012	
7	.....	.....	98.500	67.000	1.863
8	.....	.....	153.639	103.750	1.364
9	.....	.....	199.207	114.222	1.012
10	.....	.....	156.131	112.750	1.364
.....	607	645.713	1570.818	991.347	14.081	

Average water-pressure..... 157.0818
 Average steam-pressure..... 99.1347
 Average height thrown..... 202.33
 Distance..... 215.2376

Average diameter of pro-rata nozzles.... 1.4081
 Aggregate construction marks..... 51.337
 Pounds of coal..... 8715
 Pounds of wood..... 280.75

TABLE O.

AVERAGE LENGTH OF STREAM THROWN VERTICALLY AND HORIZONTALLY, AND AVERAGE PRESSURES OF WATER AND STEAM MAINTAINED BY BUTTON ENGINE, No. 8, DURING TRIALS OF SEPTEMBER 5, 6, 7, 8, 1876.

NO. OF TRIAL.	AVERAGE WATER-PRESSURE. POUNDS PER SQUARE INCH.	AVERAGE STEAM-PRESSURE. POUNDS PER SQUARE INCH.	DIAMETER OF PRO-RATA NOZZLES. INCHES.	REMARKS.
1	83.166	65.600	1.636	One-half pint of oil.
2	000.000	.....	1.195
3	000.000	.....	0.888
4	000.000	.....	1.636
5	000.000	.....	1.195
6	000.000	.....	0.888
7	000.000	.....	1.636
8	000.000	.....	1.195
9	000.000	.....	0.888
10	000.000	.....	1.195
.....	83.166	65.600	12.362	

Average water-pressure..... 8.3166
 Average steam-pressure..... 65.600
 Average diameter of pro-rata nozzles.... 1.2352

Aggregate construction marks..... 46.694
 Pounds of coal..... 287.5
 Pounds of wood..... 65

TESTS OF TURBINE WATER-WHEELS.

PHILADELPHIA, Nov. 21, 1876.

JOHN S. ALBERT, ESQ.,

Chief of Bureau of Machinery.

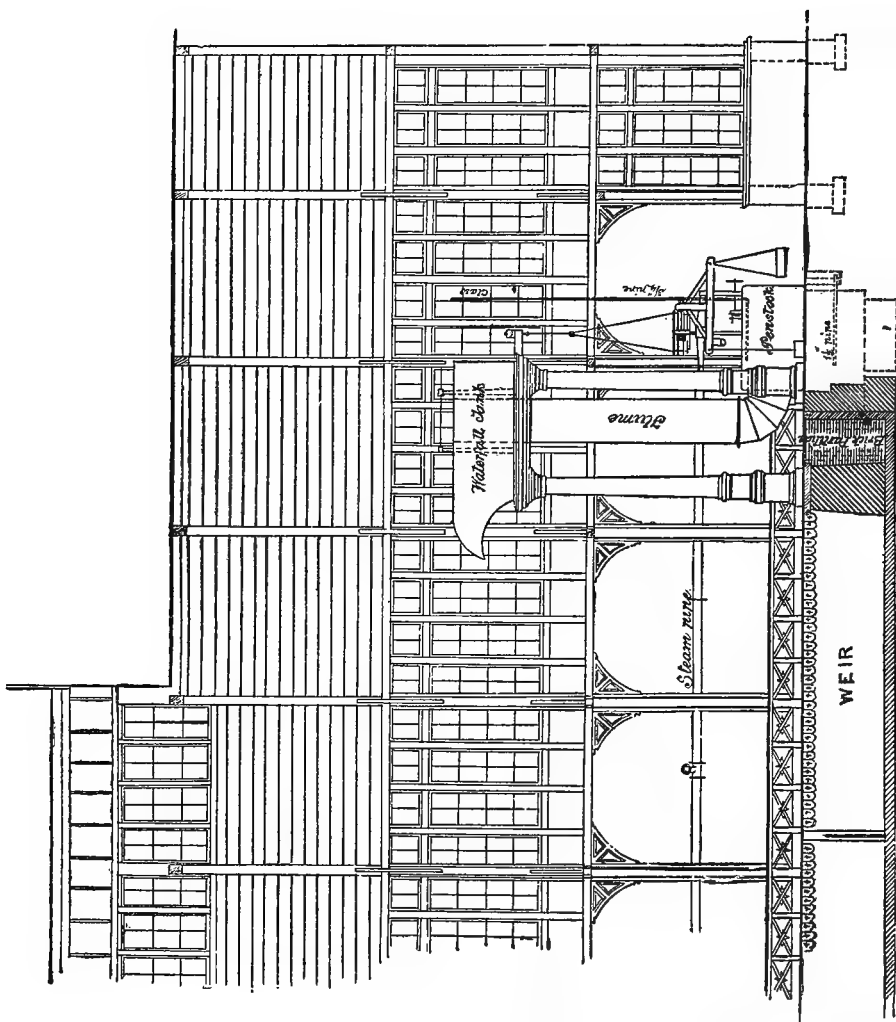
DEAR SIR,—I herewith inclose you the records of the tests of Turbine Water-Wheels made by me, at your request, in the Hydraulic Department of Machinery Hall, and, that the whole matter may be perfectly understood, will commence with a recapitulation of the apparatus employed for the purpose.

The water was furnished by a pair of powerful centrifugal pumps, exhibited by Messrs. W. L. Andrews & Co., of New York, and driven by oscillating engines, which raised from 1800 to 1900 cubic feet of water per minute to a tank placed at the end of the Hydraulic Annex, the overflow of which was 33 feet above the level of the water in the large tank in the centre of the building, from which it was pumped.

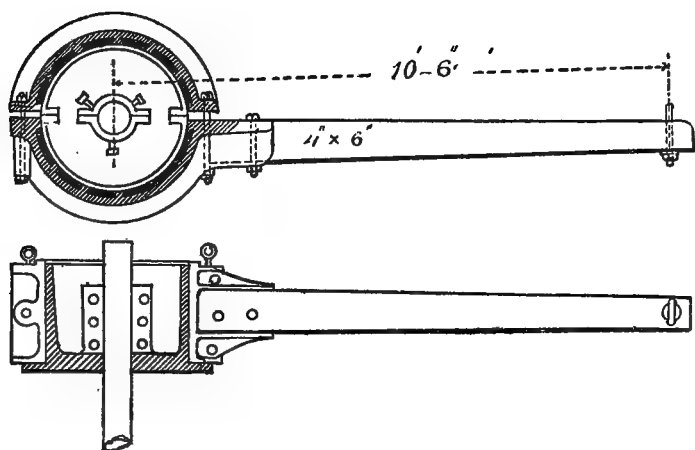
This water usually formed the "cataract," which was stopped partially or wholly while testing the Turbines.

From this tank a wrought-iron tube or "penstock" 4 feet in diameter descended to the "flume," or case in which the wheels were set, and which was 8 feet in diameter by 6 feet in height, supported by a brick wall resting on a granite bedstone. From the wheels the water was conducted by an ample passage to a rack, or strainer, 30 feet from the wheel, and stretching across a brick tail-race 14 feet wide by 8 deep, at the lower end of which, 15 feet below the rack, was the measuring weir, 9 feet long, formed of a heavy cast-iron plate planed to a true edge $\frac{1}{8}$ of an inch thick, and beveled from that on the further side at an angle of 45° . The upright ends of the weir were made of Georgia pine, cut and beveled to the same dimensions, and were carefully adjusted by Mr. Samuel S. Webber, and verified by myself.

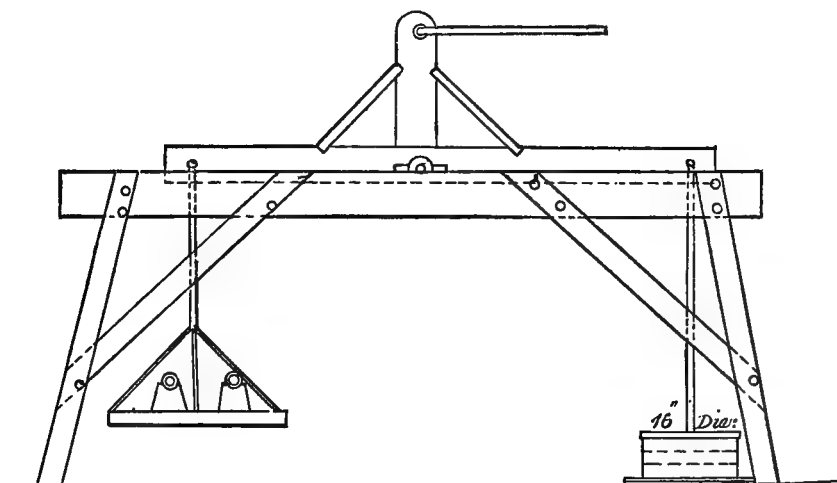
The hook gauge, loaned for the experiments by Mr. T. H. Risdon, was placed in a tight wooden box 6 feet up-stream from the weir, and the water was admitted to this box, for the purpose of measurement of height, by a few $\frac{3}{8}$ inch holes bored in the bottom of the box, 3 feet below the surface of the water; and an examination of the very



HYDRAULIC ANNEX—APPARATUS



Wheel 37.44' diam., 18' face, 1000 lbs. weight. Brake 1600 lbs. weight, leverage 132:1.



BRAKE FOR TESTING TURBINE WHEELS.

thorough test of the Tait wheel shows the sensitiveness with which the weir measurement responded to the changes of load and variation in the number of revolutions of the wheel.

The apparatus for measuring the power consisted of a friction pulley fitted to the wheel shaft, 37.44 inches diameter and 18 inches face, which was clasped by a Prony-break, consisting of a pair of cast-iron shoes lined with wood, from one of which projected an oak arm 6 by 4 inches, through which a knife-edged eye-bolt was fastened at a distance from the centre of shaft of 10.50 feet, or the radius of a 66 feet circle. These portions of the apparatus, with the scale, pan, and hydraulic regulator, 16 inches diameter, were also kindly loaned by Mr. Risdon.

To facilitate the handling of the weights, this lever was connected by an iron rod with the short arm of a bell-crank or scale beam 2 feet in height, while the longer arms, which were attached to the scale, pan, and regulator, were 4 feet each, thus giving a leverage of 132 to 1 for each pound placed in the scale. All the pivots or bearings of this scale-beam were of steel, knife-edged and bearing in hardened iron sockets.

The weights used were United States standard, and were kindly loaned by Messrs. Fairbanks & Co. The pulley, weighing 1000 pounds, rested on the shaft and step of the wheel, corresponding in some measure to the usual "crown gear;" but the brake, which weighed 1600 pounds, was suspended by a swivel from a beam directly over the centre of the wheels, so as to allow perfect freedom of motion in any direction. An examination of the records will also show the sensitiveness and accuracy of this part of the apparatus, every distance and dimension of which I carefully measured and adjusted personally before commencing the tests.

The head of water acting on the wheels was ascertained by a gauge-rod, having a hook at the lower end, which was carefully kept at the level of the tail-water in a box sunk in the floor and connected with the tail-race by a perforated pipe; while a pipe led from the case to the level of the head water, where a glass tube enabled the observer to read at once the acting head, by the graduations on the upper end of the gauge rod.

Experiments not strictly belonging to the wheel tests were made, showing that the same wheel, with the same load, at different times repeated the number of revolutions very accurately, and proved the correctness of the apparatus. The revolutions of the wheel were ascertained by a worm-gear clock, which was thrown in and out of connection with the shaft of the wheel, at signals given by a bell, which

was struck at intervals of 1 or 2 minutes, according to the length of test desired.

The friction pulley was accurately balanced before commencing the tests, and, when the wheels themselves were truly set, ran with perfect steadiness and regularity.

In conducting these tests I have been assisted by the following gentlemen, our watches being all set to the same time before commencing the tests, and simultaneous observations being taken during their entire duration. These observations being noted down as taken, a comparison of the different note-books gave a record of all the points in the test at every half-minute of its duration.

Mr. Percy Sanguinetti read the hook gauge, giving the height of water on the weir; Mr. P. W. Voorhees read the gauge giving the head of water acting on the wheel; Mr. Samuel S. Webber managed the counting clock and read the revolutions of the wheel, and also saw that the lubrication was perfect; while Mr. John Cotter, Superintendent of the Hydraulic Annex, kept the records of the weight and revolutions, and assisted me generally in various ways. I personally kept an eye on all points, and gave the bell-signals by which the observations were taken; and to all of the above-named gentlemen who assisted me I desire to return my thanks for their fidelity to their duties, and their active co-operation, as well as to Mr. Johnson, who handled the wrench by which the friction of the break was regulated, and to the engineers in charge of the Andrews pumps for their uniform patience and courtesy under, at times, very trying circumstances, and also to all the employees who took charge of the less prominent but not less important parts of the operations.

Each exhibitor was allowed free access and liberty of observations during the tests of his own wheel; and, whatever may be the accuracy of the net results obtained, the comparative ones may be depended on, as the tests were all made under similar circumstances, and the different points watched and the notes taken throughout by the same observers, none of them having any interest whatever in the result, or any opportunity at the time of knowing what the observations were at other stations than their own.

It is worthy of notice that the best results have been attained by wheels taken just as they came from the shop, without any especial finish or preparation, and the thoroughly exhaustive test of the Tait wheel is worth studying, as showing the accurate working of the apparatus.

The Geyelin wheel, entered by R. D. Wood & Co., was so tightly fitted in the shop that I do not think we got a fair record of its power;

and the Cope wheel used so much water that we could not carry the test out in full, but the percentage was gaining regularly up to the last trial, when we exhausted the supply of water, having reached over 1860 cubic feet, or about 14,000 gallons, per minute.

The Hunt wheel also taxed the supply of water to the utmost. The Tyler wheel was too loose in the upper bearing on the second trial, and the third wheel, from the York Co., was only tested to prove or disprove what was believed to be an unsound principle, viz., that of shallow buckets and central discharge; and the result is confirmed by those obtained from some of the other wheels.

The leakage of the flume was large during the first 6 trials, but by caulking and tamping with lead was very much reduced at the test of the Tyler wheel, after which test the allowance was uniform of 14.352 cubic feet per minute waste to each wheel. In the first 6 tests it was taken as noted in the tables, and the amount is in all cases deducted from the water consumed per minute.

Believing that this report will afford all necessary explanation of the Tables, and thanking you and the other officers of the Machinery Department for your cordial assistance and co-operation, I remain

Very truly yours,

SAMUEL WEBBER,

Superintending Engineer Centennial Turbine Tests.

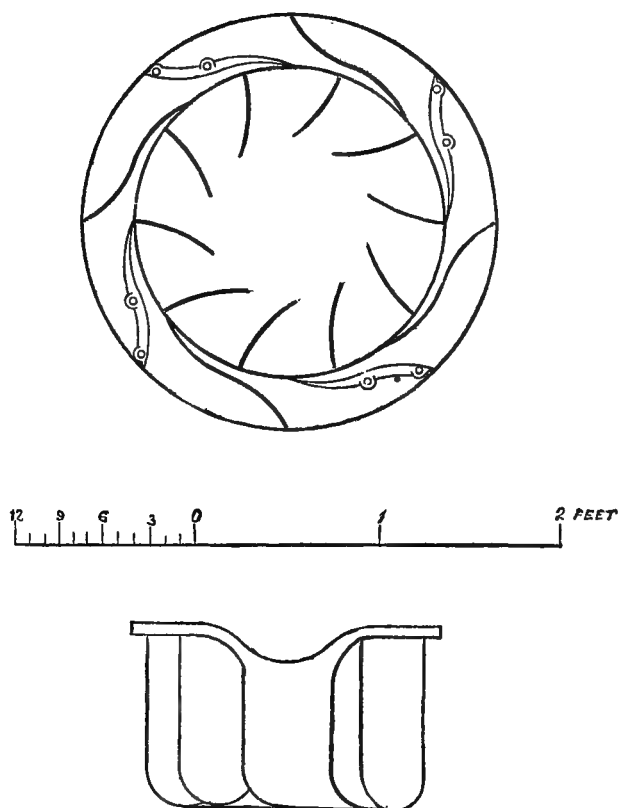
TESTS OF WATER-WHEELS.

SEPTEMBER 18, 1876. BARBER & HARRIS, MEAFORD, PROVINCE OF ONTARIO, CANADA.
WHEEL 20 IN. DIAMETER.

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	P.M. 5.05	P.M. 5.07	23	354	31.25	.620	812.48	32.568	48.00	67.85	.096	Full Gate.
2	5.08	5.10	26	348.5	31.22	.623	818.71	36.244	48.309	75.1	.096	"
3	5.13	5.15	27	341.5	31.18	.630	833.28	36.882	49.107	74.69	.096	"
4	5.18	5.19	28	330.5	31.18	.626	824.95	37.016	48.61	76.08	.096	"
5	5.21	5.23	22	380.5	31.27	.600	771.29	33.484	45.58	73.62	.096	$\frac{3}{8}$ Gate.
6	5.27	5.29	22	267.5	31.40	.514	624.75	23.540	35.64	66.09	.096	$\frac{3}{4}$ Gate.
7	5.30	5.32	20	299	31.45	.495	566.1	23.92	33.65	71.30	.096	"
8	5.40	5.42	16	271.5	31.62	.405	406.01	17.376	24.26	71.77	.096	$\frac{1}{2}$ Gate.
9	5.47	5.49	13	227.5	31.66	.405	406.01	11.83	24.29	48.7	.096	"

Correct copy of notes.

SAMUEL WEBBER.



BARBER & HARRIS.

20 in. Wheel.

Number of buckets.	10		
Number of gate openings	8		
4 movable and 4 stationary gates	8 $\frac{1}{8}$	inches deep.	
Buckets, greatest area of discharge	570	square inches.	
Buckets, least area of discharge	88.60	" "	
Gate openings, least area of discharge	103.52	" "	
Gate openings, greatest area of discharge	650	" "	

TESTS OF WATER-WHEELS.

SEPTEMBER 21, 1876. T. H. RISDON & Co., MOUNT HOLLY, N. J. WHEEL 30 IN.
DIAMETER.

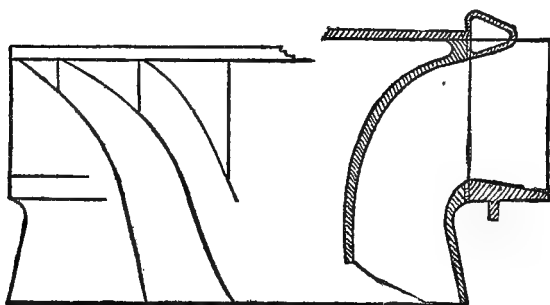
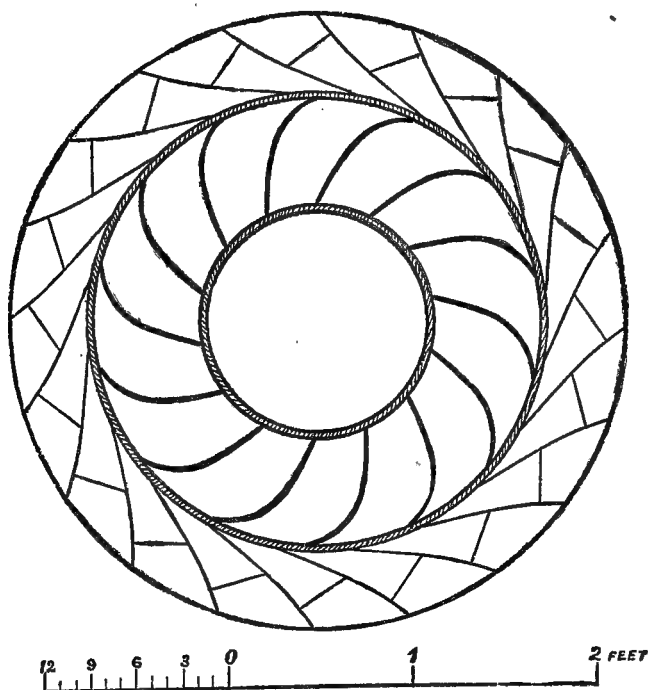
NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	P.M. 1.07	P.M. 1.09	78	266	30.38	.973	1653.85	82.99	94.96	87.68	.072	Full Gate.
2	1.10	1.12	80	258.5	30.36	.9795	1670.60	82.72	95.86	86.55	.072	"
3	1.13	1.15	82	252.5	30.37	.9804	1672.91	82.82	96.02	85.44	.072	"
4	1.18	1.20	68	257	30.59	.8738	1402.67	69.90	81.26	86.20	.072	¾ Gate.
5	1.21	1.23	70	247	30.59	.876	1410.98	69.16	81.57	85.00	.072	"
6	1.26	1.28	60	238	30.83	.795	1217.47	57.12	70.94	81.125	.072	¾ Gate.
7	1.31	1.33	58	248	30.84	.7876	1200.24	57.54	69.96	82.41	.072	"
8	1.38	1.40	38	269	31.05	.677	951.9	40.89	55.86	73.16	.072	¾ Gate.
9	1.41	1.43	40	263.5	31.04	.680	958.44	42.16	56.22	75.13	.072	"
10	1.44	1.46	41	258	31.00	.681	960.61	42.31	56.28	75.35	.072	"

N.B.—A full gate test at 280 revolutions per minute showed a better apparent result than either of the above, but is omitted from a little uncertainty as to the weir reading.

The power attained was 85.42 P.

Correct copy of notes.

SAMUEL WEBBER.



T. H. RISDON & CO.

30 in. Wheel.

DOWNWARD DISCHARGE.

Number of buckets in wheel	14
Number of gate openings	20
Area of guides at least cross-section	184.2 square inches.
Least width of gate openings	1 1/8 inches.
Greatest width of gate openings	2 7/8 "

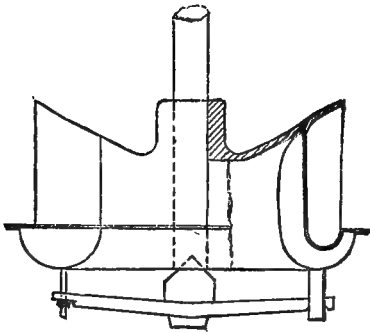
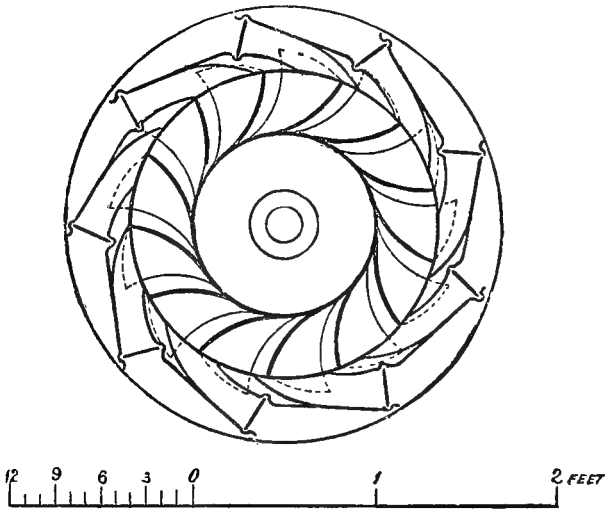
TESTS OF WATER-WHEELS.

SEPTEMBER 23, 1876. KNOWLTON & DOLAN, LOGANSFORT, INDIANA. WHEEL 24 IN. DIAMETER.

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	P.M. 12.26	P.M. 12.28	50	333.5	30.81	.908	1482.3	66.7	86.31	77.43	.082	Full Gate.
2	12.29	12.31	52	324	30.79	.9195	1510.89	67.39	87.92	76.81	.082	"
3	12.38	12.40	54	311	30.75	.923	1519.7	67.18	88.31	76.22	.082	"
4	12.41	12.43	56	302	30.76	.924	1522.2	67.65	88.49	76.61	.082	"
5	12.44	12.46	58	293.5	30.74	.928	1532.2	68.09	89.02	76.72	.082	"
6	12.48	12.50	60	282.5	30.73	.931	1533.9	67.80	89.43	76.28	.082	"
7	12.52	12.54	48	299.5	30.85	.853	1347.59	57.50	78.57	73.34	.082	$\frac{3}{8}$ Gate.
8	12.55	12.57	50	292.5	30.86	.856	1354.86	58.50	79.02	72.30	.082	"
9	12.58	1.00	52	283.5	30.88	.859	1362.12	58.97	79.50	72.43	.082	"
10	1.05	1.07	38	*233	31.18	.684	959.6	35.42	56.55	62.73	.082	$\frac{1}{2}$ to $\frac{5}{8}$ Gate.
11	1.08	1.10	36	243.5	31.18	.684	959.6	35.06	56.55	62.13	.082	"
12	1.11	1.13	34	256.5	31.19	.683	957.42	34.88	56.43	61.94	.082	"
13	1.14	1.16	32	270.5	31.21	.678	946.58	34.62	55.83	62.14	.082	"

Correct copy of notes.

SAMUEL WEBBER.



KNOWLTON & DOLAN.

24 in. Wheel.

Number of gate openings	9
Number of buckets	13
Least area of discharge buckets	195 square inches.
Least area of gate openings	144 " "
Greatest area of gate openings	180 " "

TESTS OF WATER-WHEELS.

SEPTEMBER 25, 1876. A. N. WOLFF, ALLENTOWN, PA. WHEEL 24 IN. DIAMETER.

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	P.M. 12.21	P.M. 12.23	64	266	30.58	.977	1664.15	68.10	96.18	71.13	.072	Full Gate.
2	12.24	12.26	62	274	30.59	.975	1659.03	67.95	95.92	70.91	.072	"
3	12.27	12.29	60	287.5	30.58	.9715	1650.07	69.00	95.37	72.58	.072	"
4	12.30	12.32	58	297	30.60	.968	1641.06	68.90	94.90	72.75	.072	"
5	12.33	12.35	56	305	30.60	.960	1620.66	68.32	93.73	72.80	.072	"
6	12.42	12.44	55	303.5	30.58	.963	1628.32	66.77	94.11	71.35	.072	"
7	12.45	12.47	57	297.5	30.56	.961	1623.21	67.83	93.754	72.69	.072	"
8	12.49	12.51	50	276.5	30.79	.842	1328.69	55.30	77.321	71.5	.072	¾ Gate.
9	12.52	12.54	44	297.5	30.83	.830	1300.64	52.36	75.75	69.1	.072	"
10	1.00	1.02	30	287.5	31.08	.660	915.38	34.50	53.77	64.9	.072	½ Gate.
11	1.09	1.11	24	272.5	31.40	.572	733.38	26.16	43.524	60.22	.072	½ Gate.
12	1.19	1.21	22	282.5	31.45	.560	709.54	24.86	42.175	59.28	.072	"

Correct copy of notes.

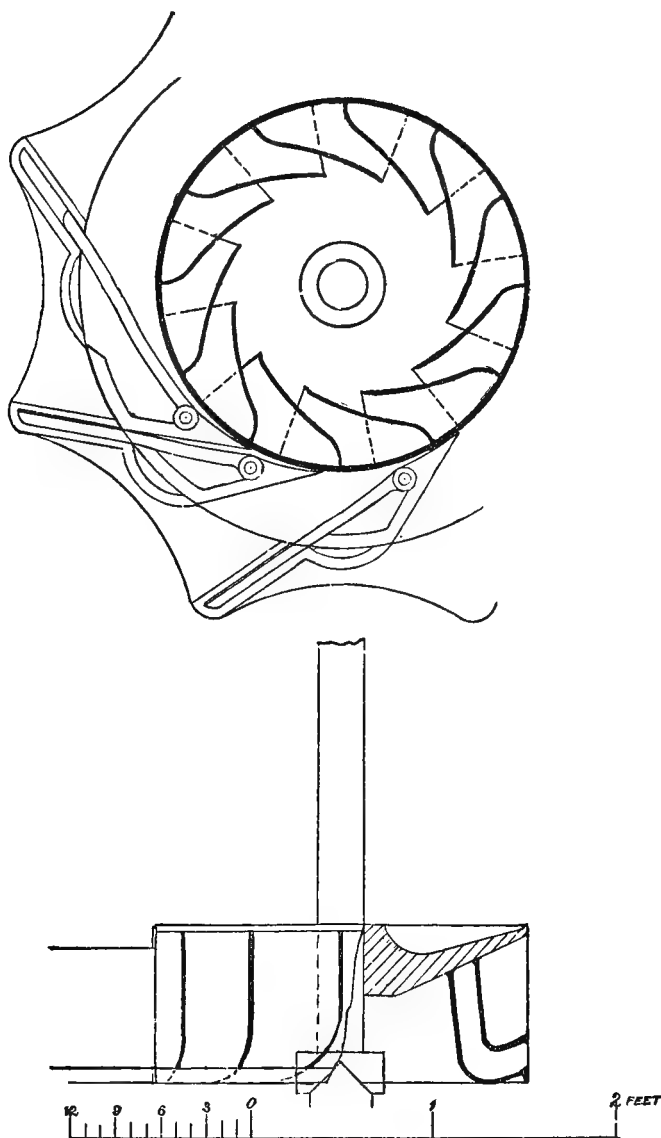
SAMUEL WEBBER.

OCTOBER 15, 1876. A. N. WOLFF, ALLENTOWN, PA. (SECOND TEST.) WHEEL 24 IN. DIAMETER.

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	P.M. 4.34	P.M. 4.36	54	300	30.18	.913	1522.55	64.80	86.85	74.64	.040	Full Gate.
2	4.37	4.39	56	291.5	30.16	.918	1535	65.30	87.50	74.68	.040	"
3	4.41	4.43	58	275	30.12	.923	1547.5	63.80	88.09	72.49	.040	"
4	4.44	4.46	60	267.5	30.12	.926	1555	64.20	88.52	72.50	.040	"
5	4.48	4.50	52	312	30.17	.910	1514.38	64.90	86.35	74.07	.040	"
6	4.55	4.56	50	320	30.16	.905	1502.6	64.00	85.65	74.80	.040	"
7	4.57	4.59	52	307.5	30.14	.909	1512.59	63.96	86.16	74.20	.040	"
8	5.04	5.06	40	300	30.58	.762	1161.5	48.00	67.13	71.50	.040	¾ Gate.
9	5.07	5.08	42	298	30.56	.766	1170.1	50.06	67.62	74.00	.040	"
10	5.10	5.11	30	284	30.83	.644	901.69	34.08	52.54	65.00	.040	½ Gate.
11	5.17	5.18	24	290	30.89	.582	773.71	27.84	45.17	61.60	.040	½ Gate.
12	5.19	5.20	26	271	30.90	.588	785.84	28.18	45.89	61.48	.040	"

Correct copy of notes.

SAMUEL WEBBER.



A. N. WOLFF.

24 in. Wheel.

Number of buckets in wheel	. . . . .	12
Number of gate openings	. . . . .	8
Area of discharge	. . . . .	186.92 square inches.
Area of guides at least cross-section	. . . . .	200 " "
Area of gate openings $8 \times (8 \times 2\frac{1}{2})$	. . . . .	160 " "

TESTS OF WATER-WHEELS.

SEPTEMBER 26, 1876. JOHN T. NOYES & SONS, BUFFALO, N. Y. WHEEL 24 IN.
DIAMETER.

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	P.M. 3.28	P.M. 3.30	32	285	31.11	.697	995.52	36.48	58.53	62.37	.072	Full Gate.
2	3.32	3.34	34	269	31.10	.698	997.71	36.58	58.64	62.42	.072	"
3	3.35	3.37	30	294	31.10	.691	982.39	35.28	57.74	61.23	.072	"
4	3.38	3.40	28	302.5	31.11	.686	971.44	33.88	57.12	59.64	.072	"
5	3.41	3.43	26	317	31.16	.630	851.96	32.97	50.17	65.46	.072	$\frac{3}{8}$ Gate.
6	3.45	3.47	26	289	31.24	.620	831.12	30.06	49.072	61.27	.072	$\frac{3}{4}$ Gate.
7	3.48	3.50	24	300	31.21	.615	820.76	28.80	48.414	60.26	.072	"
8	3.51	3.53	22	314	31.17	.608	806.33	27.63	47.50	58.40	.072	"
9	3.55	3.57	22	293	31.29	.542	674.23	25.78	39.87	64.80	.072	$\frac{5}{8}$ Gate.
10	4.02	4.04	20	256.5	31.28	.536	662.59	20.52	39.17	52.52	.072	$\frac{1}{2}$ Gate.
11	4.05	4.07	18	272.5	31.28	.528	647.16	19.62	38.26	51.45	.072	"
12	4.08	4.10	16	289.5	31.28	.520	631.84	18.52	37.35	50.05	.072	"

SEPTEMBER 27, 1876.

13	12.24	12.26	30	302	31.00	.684	967.12	36.24	56.66	64.0	.072	Full Gate.
14	12.27	12.29	28	317	30.95	.665	926.09	35.50	54.17	65.66	.072	"
15	12.30	12.32	26	325	30.80	.664	923.95	33.80	53.78	62.95	.072	"
16	12.33	12.35	27	320	30.64	.668	932.53	34.56	54	64.14	.072	"

Correct copy of notes.

SAMUEL WEBBER.

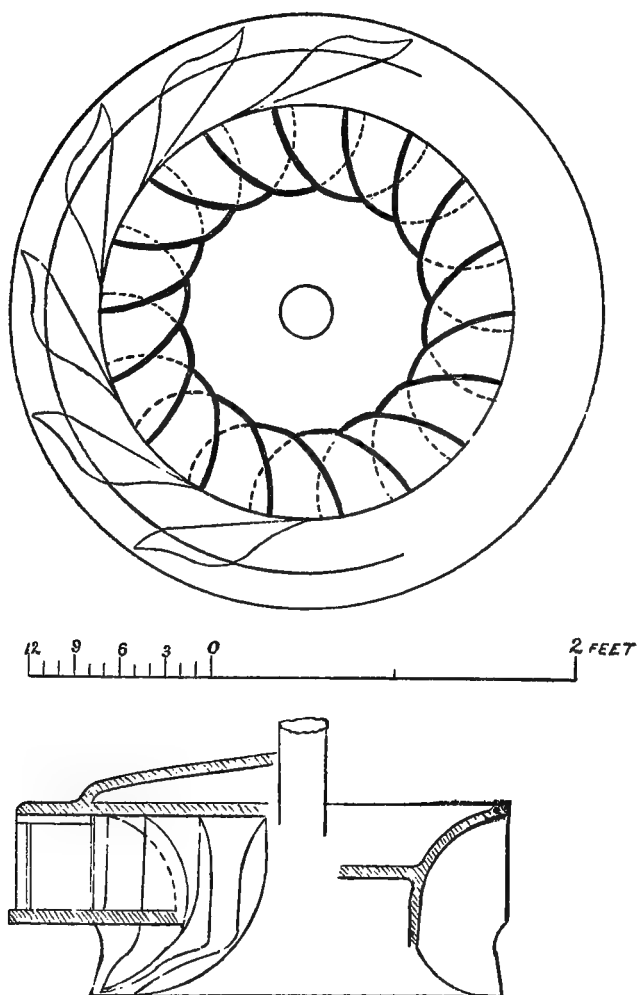
TESTS OF WATER-WHEELS.

OCTOBER 2, 1876. GOLDIE & McCULLOUGH, GALT, PROVINCE OF ONTARIO, CANADA.
WHEEL 27 IN. DIAMETER.

NUMBER OF TEST.	TIME OF START.		TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	P.M. 12.18	P.M. 12.20	52	320	30.25	.945	1582.55	66.56	90.48	73.30	.072		Full Gate.
2	12.21	12.23	54	316	30.27	.950	1595.22	68.25	91.26	74.98	.072		"
3	12.27	12.29	58	303.5	30.27	.963	1628.29	70.41	93.15	75.77	.072		"
4	12.30	12.32	60	301	30.24	.968	1641.09	72.24	93.79	77.15	.072		"
5	12.33	12.35	62	299	30.20	.972	1651.34	74.15	94.25	78.80	.072		"
6	12.36	12.38	64	296.5	30.20	.974	1656.40	75.90	94.54	80.3	.072		"
7	12.39	12.41	66	291	30.18	.982	1677.03	76.82	95.66	80.3	.072		"
8	12.42	12.44	68	286.5	30.12	.984	1682.17	77.92	95.76	81.68	.072		"
9	12.45	12.47	70	281.5	30.05	.988	1692.47	78.82	96.12	82.2	.072		"
10	12.49	12.51	50	280	30.14	.858	1367.22	56.00	77.88	71.93	.072		¾ Gate.
11	12.52	12.54	48	285	30.15	.861	1374.47	54.72	78.32	70.0	.072		"
12	12.57	12.59	26	352	30.63	.848	1343.1	36.61	77.75	47.20	.072		⅝ Gate.
13	1.02	1.04	30	350	30.55	.850	1347.91	42.00	77.83	54.10	.072		"
14	1.07	1.09	30	325	30.65	.782	1187.25	39.00	68.77	56.7	.072		½ Gate.
15	1.10	1.12	34	312	30.65	.792	1210.46	42.43	70.121	60.5	.072		"

Correct copy of notes.

SAMUEL WEBBER.



GOLDIE & McCULLOUGH.

27 in. Wheel.

Number of buckets.	18
Number of openings in case	11
Width of openings in case at least cross-section	$2\frac{1}{8}$ inches.
Depth of openings in case at least cross-section	$5\frac{3}{8}$ "
Area of gate case at least cross-section	173.679 square inches.
Area of discharge of buckets at least cross-section	175.50 " "

TESTS OF WATER-WHEELS.

OCTOBER 4, 1876. PUTNAM MACHINE CO., FITCHBURG, MASS. TYLER WHEEL 30 IN. DIAMETER.

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.*	REMARKS, ETC.
1	P. M.	P. M.	74	251	30.00	.972	1671.63	74.29	94.78	78.32	.040	Full Gate.
2	12.21	12.23	72	257	30.05	.960	1640.96	74.02	93.20	79.55	.040	"
3	12.28	12.30	72	278	30.05	.955	1628.21	71.17	92.47	77.36	.040	"
4	12.31	12.33	64	285.5	30.06	.948	1610.46	70.80	91.50	75.64	.040	"
5	12.34	12.36	62	288.5	30.10	.945	1602.87	69.24	91.18	75.87	.040	"
6	12.37	12.39	60	294	30.08	.944	1600.34	68.21	90.98	75.27	.040	"
7	12.40	12.41	58	282.5	30.05	.958	1635.87	72.32	92.90	77.83	.040	"
8	12.46	12.48	64	277	30.02	.959	1638.41	73.13	92.96	78.66	.040	"
9	12.51	12.52	66	286.5	30.10	.880	1441.06	66.47	81.98	81.09	.040	3/8 Gate.
10	12.54	12.56	58	261	30.25	.814	1282.38	58.40	73.32	79.85	.040	3/4 Gate.
11	12.58	12.59	56	246	30.47	.807	1265.88	51.17	72.90	70.24	.040	"
12	1.00	1.02	52	256.5	30.52	.788	1221.45	49.25	69.45	70.9	.040	"
13	1.03	1.05	48	247	30.60	.745	1122.81	43.47	64.94	67.10	.040	1/2 Gate.
14	1.07	1.09	44	260	30.65	.730	1089	41.60	63.08	66.00	.040	"
15	1.10	1.12	40	240	30.80	.622	855.57	34.56	49.80	60.50	.040	1/3 Gate.
15	1.14	1.15	36									

* The waste of weir was 14.352 cubic feet per minute.

Correct copy of notes.

SAMUEL WEBBER.

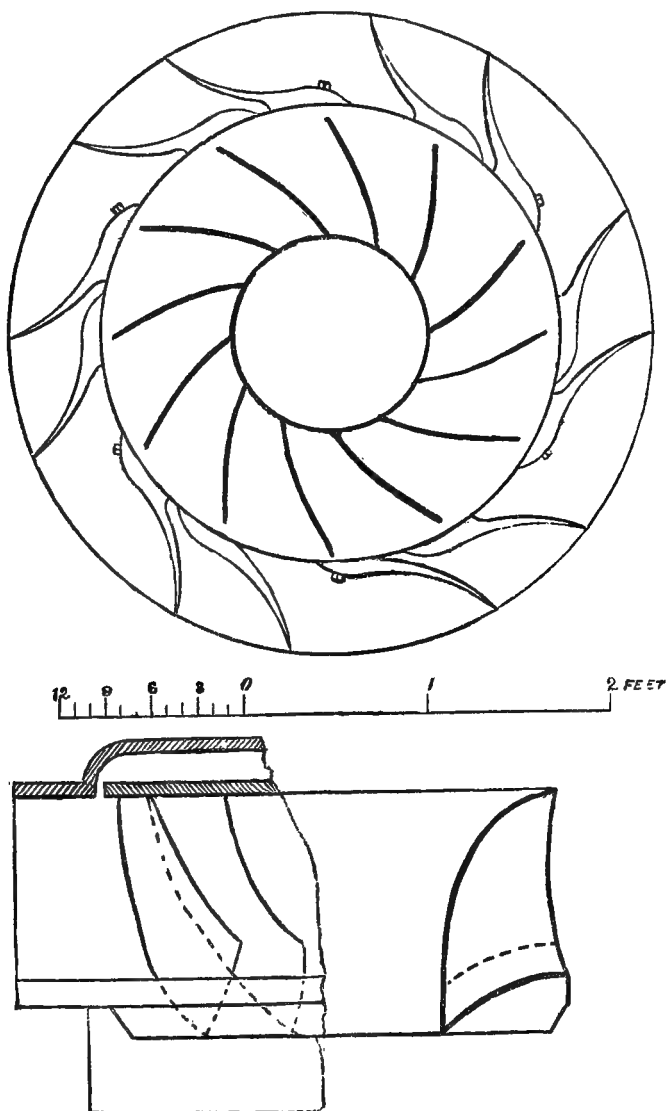
OCTOBER 24, 1876. PUTNAM MACHINE CO., FITCHBURG, MASS. TYLER WHEEL 30 IN. DIAMETER. (SECOND TEST.)

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	P. M.	P. M.	68	262	30.36	.975	1679.33	71.26	96.36	73.9	.040	Full Gate.
2	3.43	3.44	66	265	30.28	.973	1674.2	69.96	95.81	73.10	.040	"
3	3.46	3.48	64	270	30.26	.964	1651.16	69.12	94.42	73.3	.040	"
4	3.49	3.50	62	281	30.35	.960	1640.96	69.60	94.13	74.10	.040	"
5	3.51	3.52	60	287	30.40	.955	1628.2	68.88	93.55	73.79	.040	"
6	3.53	3.54	58	294	30.42	.953	1623.16	68.21	93.32	73.1	.040	"
7	3.56	3.57	56	280	30.50	.902	1495.22	62.72	86.19	72.15	.040	3/8 Gate.
8	3.59	4.00	58	268	30.36	.844	1353.77	55.74	77.68	73.0	.040	3/4 Gate.
9	4.16	4.17	52	244	30.48	.778	1198.29	44.88	69.03	65.0	.040	"
10	4.21	4.23	44	255	30.48	.773	1186.79	44.02	68.41	64.2	.040	5/8 Gate.
11	4.24	4.25	42	262	30.50	.773	1186.79	44.02	68.41	64.2	.040	"
12	4.28	4.29	40	218	30.68	.688	996.12	34.88	57.76	60.4	.040	1/2 Gate.
13	4.30	4.31	36	242	30.70	.688	996.12	34.85	57.80	60.30	.040	"
13	4.33	4.34	34	247	30.73	.680	978.75	33.59	56.84	59.	.040	"

Upper bearing of shaft loosened; result, bad wheel, not steady.

Correct copy of notes.

SAMUEL WEBBER.



JOHN TYLER.

30 in. Wheel.

Number of buckets in wheel	.	.	.	.	.	.	12
Number of guides	.	.	.	.	.	.	6
Number of gates	.	.	.	.	.	.	6
Area of buckets at least cross-section	.	.	.	.	.	.	234 square inches.
Area of gates at least cross-section	.	.	.	.	.	.	324 " "

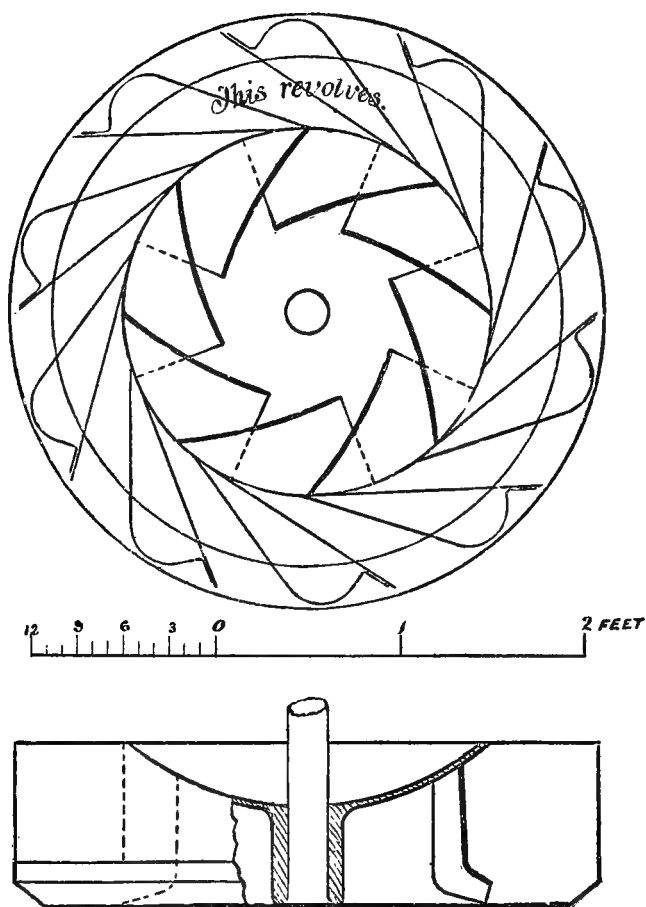
TESTS OF WATER-WHEELS.

OCTOBER 6, 1876. WM. F. MOSSER, ALLENTOWN, PA. WHEEL 24 IN. DIAMETER.

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	P.M. 12.26	P.M. 12.28	42	300	30.56	.763	1163.8	50.40	67.22	75.09	.040	Full Gate.
2	12.29	12.31	44	289.5	30.58	.772	1184.46	50.95	68.46	74.60	.040	"
3	12.32	12.34	46	276	30.58	.778	1198.29	50.78	69.26	73.40	.040	"
4	12.35	12.37	40	312.5	30.60	.770	1179.86	50	68.24	73.43	.040	"
5	12.38	12.40	38	326.5	30.60	.758	1151.36	49.63	66.58	74.62	.040	"
6	12.41	12.43	36	342	30.62	.752	1138.69	49.25	65.90	74.80	.040	"
7	12.44	12.46	34	356.5	30.65	.744	1120.55	48.48	64.91	74.39	.040	"
8	12.47	12.49	32	365	30.67	.740	1111.41	46.72	64.43	72.68	.040	"
9	12.59	1.01	32	310.5	30.90	.666	948.53	39.74	55.39	71.63	.040	
10	1.02	1.04	30	323	30.95	.657	929.27	38.76	54.36	71.48	.040	
11	1.05	1.07	28	335	31.00	.648	910.14	37.52	53.32	70.50	.040	
12	1.08	1.10	26	347	31.02	.644	901.67	36.09	52.86	68.2	.040	
13	1.11	1.13	24	355	31.03	.636	884.82	34.08	51.78	65.74	.040	
14	1.18	1.20	24	312	31.10	.595	800.04	29.95	47.02	63.80	.040	
15	1.21	1.23	22	343	31.00	.586	781.79	30.18	45.80	65.8	.040	

Correct copy of notes.

SAMUEL WEBBER.



WM. F. MOSSER & CO.

24 in. Wheel.

Number of buckets in wheel	.	.	.	.	.	8
Number of gate openings in case	.	.	.	.	.	10
Area of gate openings at least cross-section	.	.	.	.	.	125.94 square inches.
Area of discharge in wheel at least cross-section	.	.	.	.	.	126.04 " "

TESTS OF WATER-WHEELS.

OCTOBER 10, 1876. YORK MANUFACTURING CO., YORK, PA. BOLLINGER WHEEL.
26¼ IN. DIAMETER.

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	P.M. 12.40	P.M. 12.42	44	310	30.47	.855	1380.27	54.56	79.50	68.7	.040	Full Gate.
2	12.43	12.45	42	292.5	30.44	.858	1387.5	56.16	79.826	70.4	.040	"
3	12.46	12.48	46	300	30.30	.855	1380.27	55.20	79.04	69.8	.040	"
4	12.50	12.52	44	300	30	.852	1373	52.80	77.85	68.0	.040	"
5	12.55	12.57	44	290	30.46	.818	1291.8	51.04	74.37	68.6	.040	¾ Gate.
6	12.58	1.00	42	300	30.46	.816	1287	50.40	74.10	68.0	.040	"
7	1.07	1.09	36	290	30.62	.738	1107	41.76	64.06	63.6	.040	¾ Gate.
8	1.10	1.12	34	300	30.61	.737	1104.74	40.80	63.97	63.8	.040	"
9	1.13	1.14	32	306	30.62	.735	1100.24	39.17	63.67	61.3	.040	"
10	1.21	1.23	30	274.5	30.80	.663	942	32.94	54.84	60.2	.040	½ Gate.
11	1.24	1.26	28	290	30.81	.660	935.68	32.48	54.48	59.7	.040	"
12	1.34	1.36	24	263	30	.584	777.78	25.25	44.10	57.2	.040	¾ Gate.
13	1.37	1.39	20	291	31.1	.580	769.65	23.28	45.23	51.4	.040	"

Correct copy of notes.

SAMUEL WEBBER.

OCTOBER 12, 1876. YORK MANUFACTURING CO. 2D BOLLINGER WHEEL. 27 IN. DIAMETER.

1	12.35	12.37	34	312	30.59	.759	1154.6	42.43	66.75	63.6	.040	Full Gate.
2	12.38	12.40	36	306	30.55	.763	1163.80	44.06	67.19	65.6	.040	"
3	12.41	12.43	38	296	30.53	.766	1170.1	44.99	67.55	66.7	.040	"
4	12.44	12.46	40	287	30.54	.772	1184.46	45.92	68.37	67.2	.040	"
5	12.47	12.49	42	282.5	30.55	.778	1198.29	47.46	69.19	68.6	.040	"
6	12.50	12.51	44	275	30.53	.782	1207.54	48.40	69.68	69.5	.040	"
7	12.52	12.53	46	273	30.50	.790	1226.10	50.23	70.68	71.1	.040	"
8	12.54	12.56	48	270	30.50	.794	1235.43	51.84	71.22	72.8	.040	"
9	12.57	12.58	50	260	30.48	.798	1244.76	52.00	71.71	72.5	.040	"
10	1.01	1.03	52	252.5	30.44	.803	1256.50	52.52	72.29	72.9	.040	"
11	1.04	1.06	54	246.5	30.42	.804	1258.84	53.24	72.38	73.6	.040	"
12	1.08	1.09	56	232	30.42	.805	1261.2	51.97	72.51	71.7	.040	"
13	1.12	1.14	32	318	30.60	.735	1100.22	40.70	63.63	64.00	.040	¾ Gate.
14	1.15	1.17	36	300	30.60	.742	1116.0	43.20	64.54	67.00	.040	"
15	1.19	1.21	36	280	30.70	.703	1029	40.32	59.70	67.45	.040	¾ Gate.
16	1.23	1.24	34	290	30.72	.700	1022.3	39.44	59.36	66.56	.040	"
17	1.27	1.29	34	268	30.85	.656	927.14	36.45	54.06	67.50	.040	½ Gate.
18	1.30	1.32	32	277	30.85	.654	922.87	35.45	53.81	65.90	.040	"
19	1.40	1.41	24	300	31.03	.600	810.23	28.80	47.52	60.65	.040	¾ Gate.
20	1.42	1.44	26	285	31.00	.603	816.36	29.64	47.83	62.01	.040	"

Correct copy of notes.

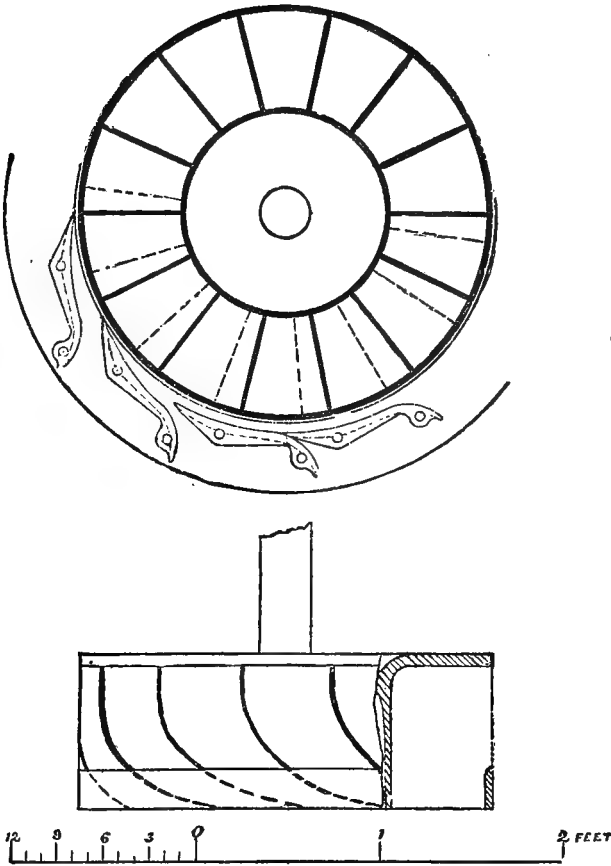
SAMUEL WEBBER.

OCTOBER 13, 1876. YORK MANUFACTURING CO. WHEEL NO. 3. 27 IN. DIAMETER.
TRIAL OF CENTRE VENT.

1	12.32	12.34	36	265.5	30.00	.830	1320.30	38.23	74.86	51.08	.040	Full Gate.
2	12.44	12.46	38	264.5	30.10	.832	1325.1	40.20	75.38	53.35	.040	"
3	12.47	12.49	40	260.5	30.05	.839	1341.8	41.68	76.21	57.3	.040	"
4	12.50	12.52	44	255	30.02	.845	1356.2	44.88	76.94	58.06	.040	"
5	12.53	12.55	46	249	30.00	.850	1368	45.81	77.38	59.10	.040	"
6	12.56	12.58	48	244	29.95	.853	1375.4	46.85	77.86	60.18	.040	"
7	12.59	1.00	52	240	29.92	.851	1370.6	49.92	77.51	64.36	.040	"
8	1.01	1.02	56	235	29.86	.860	1392.87	52.64	78.58	66.9	.040	"
9	1.03	1.05	60	212	29.85	.863	1399.64	50.88	78.96	64.4	.040	"
10	1.09	1.11	32	264	30.25	.765	1168.11	33.79	66.78	50.62	.040	¾ Gate.
11	1.15	1.16	30	251	30.48	.667	950.65	30.12	54.77	55.00	.040	"
12	1.19	1.21	34	242	30.49	.670	957.11	32.91	54.76	60.1	.040	"
13	1.22	1.23	36	233	30.46	.672	961.43	33.55	55.35	60.58	.040	"

Correct copy of notes.

SAMUEL WEBBER.



BOLLINGER.

27 in. Wheel.

Number of buckets in wheel	.	.	.	.	.	14
Number of gate openings	.	.	.	.	.	12
Least area of gate openings	.	.	.	.	.	111.35 square inches.
Least area of discharge in buckets	.	.	.	.	.	147.83 " "

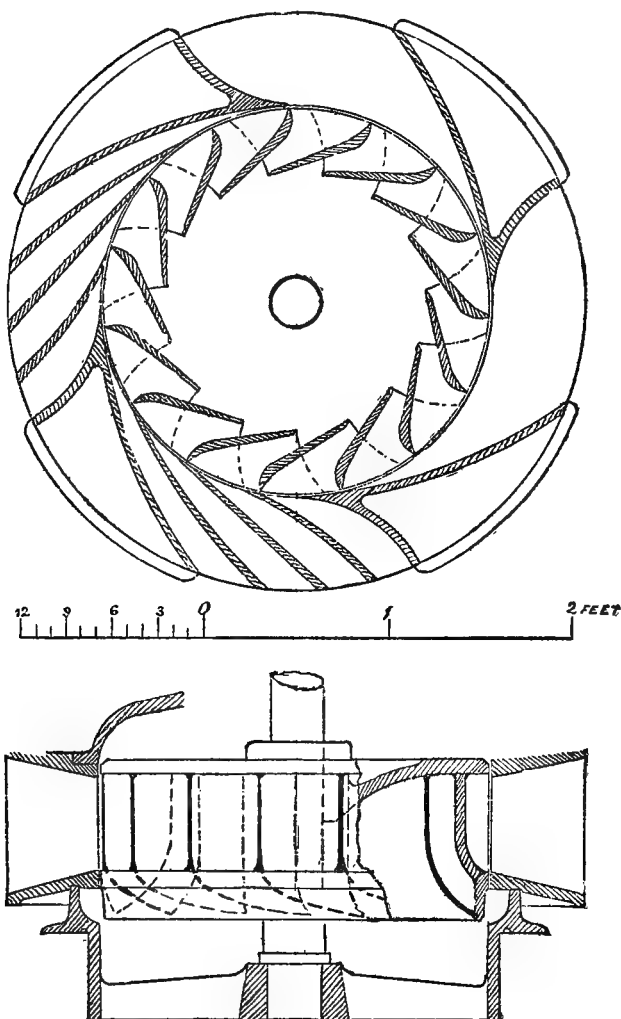
TESTS OF WATER-WHEELS.

OCTOBER 18, 1876. NATIONAL WATER-WHEEL CO., BRISTOL, CONN. WHEEL 25 IN. DIAMETER.

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	P.M. 3.28	P.M. 3.30	40	330.5	30.30	.787	1219.15	52.88	69.82	75.80	.040	Full Gate
2	3.31	3.33	46	312	30.25	.804	1258.84	57.41	71.92	79.8	.040	"
3	3.34	3.36	50	299	30.24	.814	1282.38	59.80	73.29	81.50	.040	"
4	3.37	3.39	52	290	30.22	.818	1291.8	60.32	73.78	81.7	.040	"
5	3.40	3.42	54	287.5	30.20	.825	1308.4	62.10	74.68	83.19	.040	"
6	3.43	3.45	56	279	30.17	.826	1310.81	62.49	74.74	83.7	.040	"
7	3.46	3.48	58	265	30.14	.832	1325.1	61.48	75.48	81.5	.040	"
8	3.49	3.51	60	257.5	30.13	.837	1337	61.80	76.14	81.3	.040	"
9	3.52	3.54	62	249	30.12	.840	1344.2	61.75	76.52	80.8	.040	"
10	3.56	3.58	64	241.5	30.11	.844	1353.77	61.82	77.04	80.2	.040	"
11	4.00	4.02	66	226.5	30.17	.848	1363.2	59.80	77.73	78.3	.040	"
12	4.11	4.12	32	312	30.67	.700	1022.4	39.94	59.26	67.3	.040	¾ Gate.
13	4.13	4.14	36	292	30.70	.702	1026.8	42.05	59.58	70.5	.040	"

Correct copy of notes.

SAMUEL WEBBER.



NATIONAL WATER-WHEEL CO.

25 in. Wheel. "Case Patent."

DISCHARGE DOWNWARD AND CENTRAL.

Number of buckets in wheel	15
Number of gate openings	16 (grouped in fours.)
Area of gate openings at least cross-section	105.75 square inches.
Area of discharge in buckets at least cross-section	118.125 " "

TESTS OF WATER-WHEELS.

OCTOBER 19, 1876. E. T. COPE & SONS, WEST CHESTER, PA. WHEEL 30 IN.
DIAMETER.

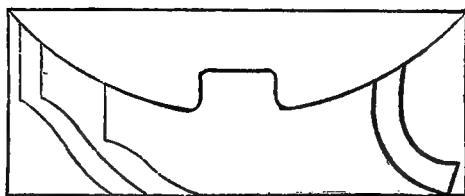
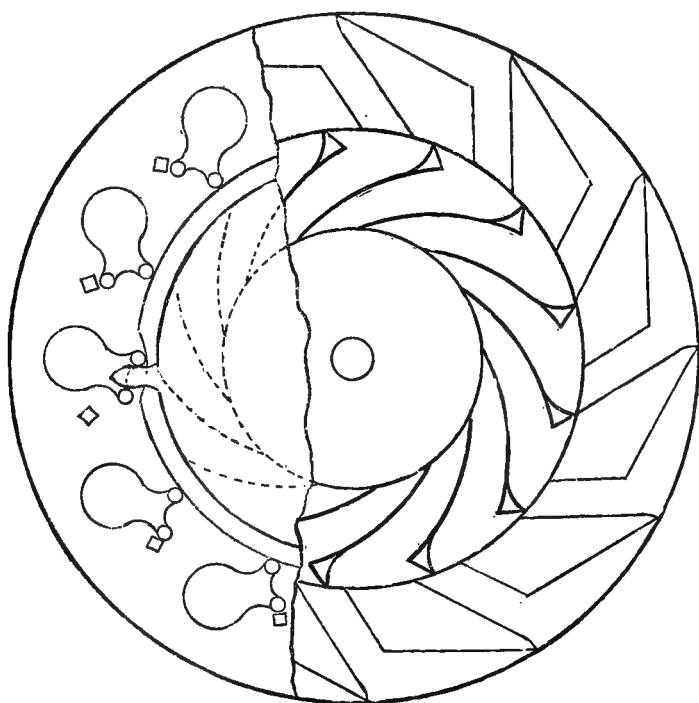
NUMBER OF TEST.	TIME OF START.		TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	P.M.	3.59	4.00	64	226	30.50	.903	1497.68	57.86	86.33	67.0	.040	Gate very close and good. All full gate.
2		4.03	4.04	60	240	30.55	.894	1475.44	57.60	85.19	67.6	.040	
3		4.05	4.06	60	245	30.54	.910	1515.1	58.80	87.45	67.3	.040	
4		4.08	4.09	56	272	30.30	.942	1595.26	60.93	91.36	66.7	.040	
5		4.10	4.11	58	266	30.26	.943	1597.8	61.71	91.38	67.6	.040	
6		4.12	4.13	60	255	30.20	.945	1602.88	61.20	91.49	66.8	.040	
7		4.14	4.15	63	254	30.00	.954	1625.69	64.01	92.17	69.4	.040	
8		4.16	4.17	67	240	29.80	.958	1635.8	64.32	92.13	69.7	.040	
9		4.19*	4.20	70	223	28.50	.954	1625.69	62.44	87.57	70.2	.040	
10		4.37	4.38	64	274	30.15	1.032	1827.6	70.14	104.14	67.3	.040	
11		4.41	4.42	76	257	29.65	1.035	1835.5	78.13	102.86	76.0	.040	
12		4.43	4.44	78	258	29.20	1.040	1848.74	80.50	102.03	78.7	.040	
13		4.45	4.46	80	241	28.80	1.040	1848.74	77.12	100.631	76.6	.040	

* Stopped to get steam up.

N.B.—Afternoon dark; steam short; tests obliged to be confined to one minute each.

Correct copy of notes.

SAMUEL WEBBER.



E. T. COPE & SONS.

30 in. Wheel.

DOWNWARD AND CENTRAL DISCHARGE.

Number of buckets in wheel	.	.	.	.	.	13
Number of gate openings	.	.	.	.	.	12
Area of gate openings	.	.	.	.	.	240 square inches.
Area of buckets at least cross-section	.	.	.	.	.	178.75 " "

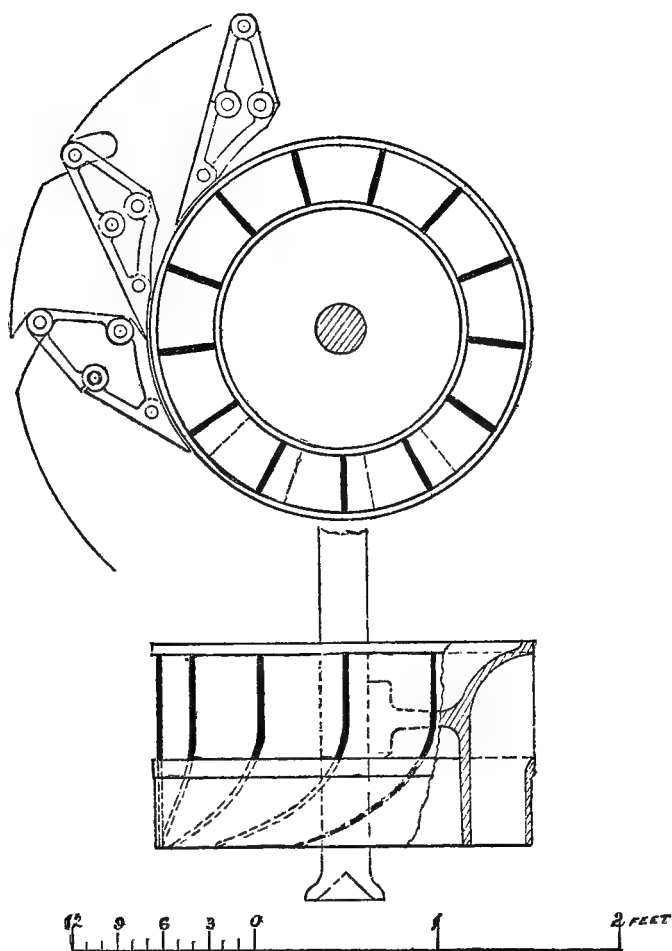
TESTS OF WATER-WHEELS.

OCTOBER 23, 1876. THOMAS TAIT, ROCHESTER, N. Y. CENTENNIAL WHEEL 25 IN. DIAMETER.

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	P.M. 12.42	P.M. 12.44	30	331	31.12	.651	916.50	39.72	53.91	73.6	.040	Full Gate.
2	12.37	12.39	32	321.5	31.06	.655	925.01	41.15	54.30	77.8	.040	"
3	12.40	12.41	34	315	31.05	.661	937.82	42.84	55.04	77.8	.040	"
4	12.34	12.36	36	300	31.03	.664	944.24	43.20	55.38	78.0	.040	"
5	12.46	12.48	38	295	31.06	.668	952.84	44.84	55.93	80.2	.040	"
6	12.31	12.33	40	288.5	31	.672	961.43	46.16	56.33	82.03	.040	"
7	12.49	12.51	42	274	31.02	.677	972.24	46.03	57.00	80.8	.040	"
8	12.53	12.54	44	265	31.01	.680	978.75	46.64	57.36	81.2	.040	"
9	12.55	12.56	46	254	31.01	.683	985.25	46.74	57.74	81.0	.040	"
10	12.57	12.58	48	243	31.02	.685	989.59	46.66	58.02	80.4	.040	"
11	1.08	1.10	22	322.5	31.32	.539	688.70	28.38	40.77	69.6	.040	¾ Gate.
12	1.04	1.06	24	302.5	31.32	.544	698.42	29.04	41.34	70.2	.040	"
13	1.12	1.13	26	292	31.32	.548	706.25	30.37	41.81	72.6	.040	"
14	1.18	1.20	20	277.5	31.45	.478	573.60	22.20	34.09	65.1	.040	½ Gate.
15	1.21	1.22	22	265	31.44	.479	575.43	22.26	34.19	65.0	.040	"
16	1.24	1.25	22	258	31.44	.480	577.27	22.70	34.30	66.2	.040	"
17	1.32	1.34	22	268.5	31.57	.370	387.03	11.81	23.09	51.3	.040	¾ Gate.
18	1.30	1.31	12	265	31.47	.373	391.89	12.72	23.31	54.5	.040	"
19	1.35	1.36	13	245	31.57	.377	398.41	12.74	23.77	53.5	.040	"
20	1.43	1.44	7	255	31.60	.305	286.49	7.14	15.25	46.9	.040	1-5 Gate.
21	1.39	1.41	8	235	31.59	.309	292.40	7.52	17.46	43.0	.040	"
22	1.47	1.48	5	277	31.61	.301	280.62	5.54	16.76	32.9	.040	¾ Gate.
23	1.45	1.46	6	266	31.61	.303	283.58	6.38	16.94	37.7	.040	"

Correct copy of notes.

SAMUEL WEBBER.



THOMAS TAIT.

25 in. Wheel.

DOWNWARD DISCHARGE.

Number of buckets (set radially)	. . . . .	13
Number of gate openings	. . . . .	10
Area of gate openings at least cross-section	. . . . .	96.25 square inches.
Area of buckets at inlet	. . . . .	241 " "
Area of buckets at discharge	. . . . .	95.976 " "

TESTS OF WATER-WHEELS.

NOVEMBER 2, 1876. GEYELIN DUPLEX TURBINE WHOLE WHEEL. 36 IN. DIAMETER.
ENTERED BY R. D. WOOD & CO., PHILADELPHIA.

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	A.M. 9.30	A.M. 9.32	76	223.5	29.53	.942	1595.28	67.94	89.04	76.3	.040	Full Gate.
2	9.36	9.38	80	217.5	29.55	.942	1595.28	69.60	89.10	78.1	.040	"
3	9.39	9.41	84	204	29.58	.942	1595.28	68.54	89.19	76.8	.040	"
4	9.42	9.44	88	195.5	29.58	.940	1590.23	68.82	88.90	77.40	.040	"
5	9.45	9.47	92	185.5	29.52	.938	1585.2	68.264	88.44	77.1	.040	"
6	9.48	9.49	90	190	29.52	.938	1585.2	68.40	88.44	77.3	.040	"
7	9.52	9.54	86	197	29.52	.940	1590.2	67.77	88.72	76.2	.040	"
8	9.55	9.56	82	206	29.56	.943	1597.8	67.57	89.266	75.6	.040	"
9	10.04	10.06	89	189	29.56	.938	1585.2	67.284	88.56	75.9	.040	"

Wheel finally withdrawn for alterations in case and step, which had worn down $\frac{3}{4}$ inch.

Correct copy of notes.

SAMUEL WEBBER.

OCTOBER 31, 1876. GEYELIN DUPLEX TURBINE. 36 IN. DIAMETER. ENTERED BY
R. D. WOOD & CO., PHILADELPHIA.

1	A.M. 9.17	A.M. 9.18	34	260	30.10	.700	1022.38	35.36	58.16	60.7	.040	Half Gate.
2	9.19	9.20	36	255	30.10	.700	1022.38	36.72	58.16	63.2	.040	"
3	9.06	9.08	38	250	30.12	.702	1026.8	38.00	58.45	65.0	.040	"
4	9.04	9.05	40	240	30.10	.700	1022.38	38.40	58.16	66.1	.040	"
5	9.23	9.24	42	235	30.30	.703	1029	39.48	58.93	66.99	.040	"
6	9.25	9.26	44	227	30.30	.703	1029	39.95	58.93	67.8	.040	"
7	9.27	9.28	46	220	30.30	.703	1029	40.48	58.93	68.7	.040	"
8	9.29	9.30	48	215	30.30	.705	1033.4	41.28	59.18	69.8	.040	"
9	9.31	9.32	50	208	30.30	.705	1033.4	41.60	59.18	70.0	.040	"
10	9.34	9.35	52	200	30.30	.708	1040.04	41.60	59.56	69.8	.040	"
11	9.37	9.38	54	196	30.28	.708	1040.04	42.33	59.52	71.17	.040	"
12	9.39	9.40	56	190	30.28	.708	1040.04	42.56	59.52	71.4	.040	"
13	9.41	9.42	58	181	30.28	.708	1040.04	41.99	59.52	70.5	.040	"

Outer row of buckets wheelbound in case. Withdrawn.

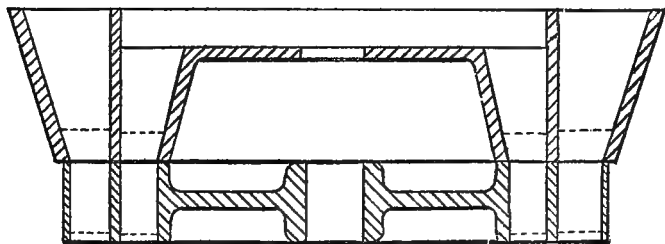
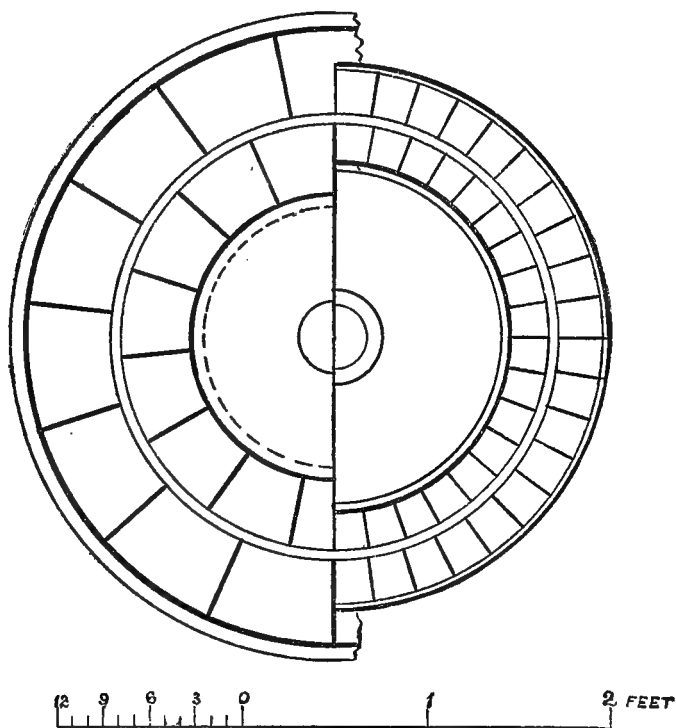
NOVEMBER 1. WHEEL EASED IN CASE.

14	P.M. 12.52	P.M. 12.54	54	205	29.95	.716	1057.76	44.28	59.87	74.0	.040	Half Gate.
15	12.55	12.56	56	199	29.96	.715	1055.56	44.57	59.77	74.60	.040	"
16	12.57	12.58	58	191	29.96	.715	1055.56	44.31	59.77	74.33	.040	"
17	12.59	1.00	60	186	29.95	.717	1059.99	44.64	60.14	74.3	.040	"

Wheel withdrawn for further easement.

Correct copy of notes.

SAMUEL WEBBER.



GEVELIN DUPLEX JONVAL.

36 in. Wheel.

Number of buckets in wheel (outer set) . . .	40
Number of buckets in wheel (inner set) . . .	36
Area of least cross-section (outer) . . .	71.843 square inches.
Area of least cross-section (inner) . . .	47.25 " "
Number of guides (outer and inner) each . . .	15

TESTS OF WATER-WHEELS.

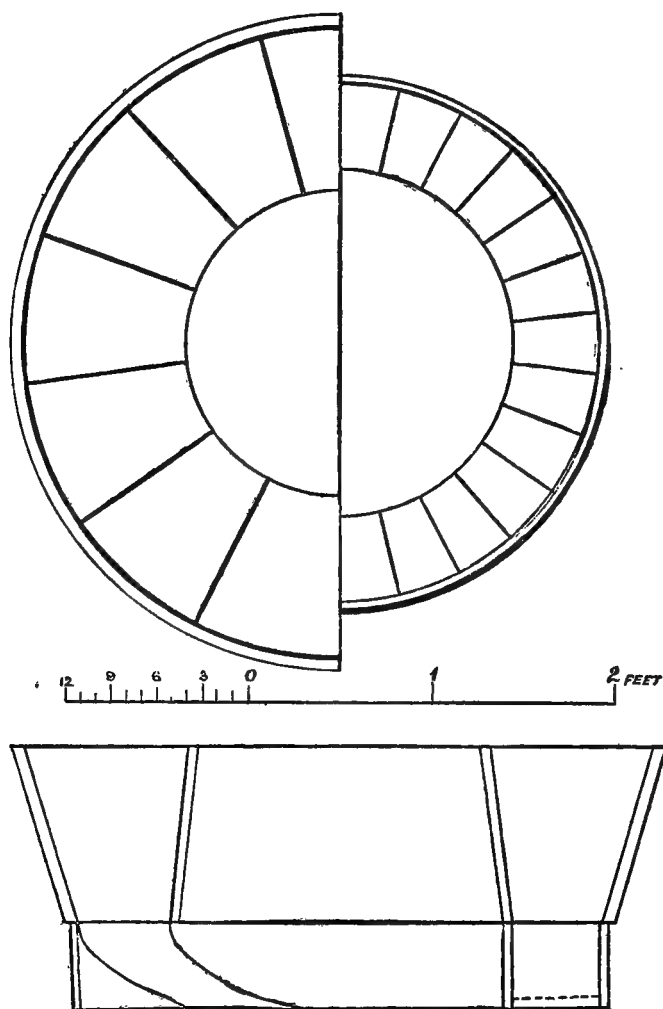
NOVEMBER 3, 1876. GEYELIN SINGLE TURBINE. 36 IN. DIAMETER. EXHIBITED BY
R. D. WOOD & Co., PHILADELPHIA.

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	A.M. 9.42	A.M. 9.44	80	213.5	29.30	.896	1480.4	68.32	81.98	83.3	.040	Full Gate.
2	9.45	9.47	82	205	29.61	.897	1482.88	67.24	82.98	81.00	.040	"
3	9.48	9.50	84	197	29.62	.903	1497.68	66.192	83.85	78.9	.040	"
4	9.51	9.53	86	190.5	29.65	.904	1500.18	65.53	84.07	77.9	.040	"
5	9.54	9.56	78	211	29.64	.900	1490.27	65.83	83.48	78.8	.040	"
6	9.57	9.58	78	212	29.62	.900	1490.27	66.144	83.43	79.2	.040	"
7	9.59	10.01	78	205.5	29.60	.900	1490.27	64.116	83.37	76.8	.040	"

This wheel also bound in the step, and as it fell away from the first trial instead of doing better, it was also withdrawn.

Correct copy of notes.

SAMUEL WEBBER.



GEVELIN SINGLE JONVAL.

36 in. Wheel.

Number of buckets in wheel	.	.	.	.	.	26
Number of buckets in guides	.	.	.	.	.	13
Area of buckets, entry	.	.	.	.	.	485.68 square inches.
Area of buckets, discharge	.	.	.	.	.	114.66 " "
Area of guides, entry	.	.	.	.	.	1042.7 " "

TESTS OF WATER-WHEELS.

NOVEMBER 6, 1876. CHASE MANUFACTURING CO., ORANGE, MASS. 24 IN. DIAMETER.

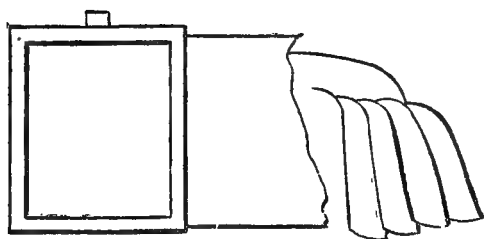
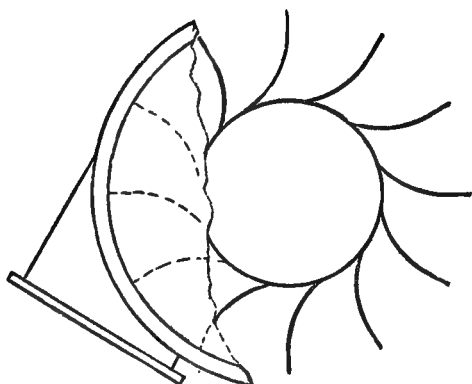
NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
	P.M.	P.M.										
1	3.28	3.30	32	399	29.30	.915	1527.5	51.07	84.59	60.43	.040	Full Gate.
2	3.31	3.33	34	380	29.35	.917	1532.5	51.68	85.03	60.7	.040	"
3	3.34	3.35	34	379	29.52	.918	1535	51.54	85.64	60.20	.040	"
4	3.36	3.38	36	366	29.70	.921	1542.5	52.70	86.58	60.80	.040	"
5	3.39	3.41	38	358	29.88	.924	1550	54.416	87.53	62.1	.040	"
6	3.42	3.44	40	349	29.98	.928	1560	55.84	88.39	63.10	.040	"
7	3.45	3.47	42	331	30	.927	1557.5	55.61	88.31	62.9	.040	"
8	3.48	3.49	44	304	29.80	.927	1557.0	53.50	87.723	61.06	.040	"

NOVEMBER 7, 1876.

9	3.49	3.51	40	365	29.85	.927	1557.0	58.40	87.87	66.4	.040	Full Gate.
10	3.53	3.54	42	355	29.80	.925	1552.5	59.64	87.44	68.30	.040	"
11	3.55	3.56	44	332	29.80	.925	1552.5	58.43	87.44	66.9	.040	"
12	3.18	3.20	44	435	29.25	.871	1419.1	48.72	78.44	62.10	.040	¾ Gate.
13	3.21	3.23	36	363.5	29.35	.866	1406.9	52.34	87.04	66.5	.040	"
14	3.24'30"	3.26'30"	38	346	29.58	.866	1406.9	52.59	78.65	66.5	.040	"
15	3.29	3.31	40	325	29.55	.867	1409.3	52.00	78.71	66.0	.040	"
16	3.31'30"	3.33'30"	37	360.5	29.62	.867	1409.3	53.354	78.90	67.6	.040	"
17	3.37'30"	3.39'30"	24	372.5	30	.748	1129.6	35.76	64.05	55.7	.040	½ Gate.
18	3.40'30"	3.42'30"	26	350	30.12	.746	1125.1	36.40	64.05	56.8	.040	"
19	3.44	3.46	28	328	30.10	.746	1125.1	36.74	64.00	57.3	.040	"

Correct copy of notes.

SAMUEL WEBBER.



CHASE MANUFACTURING COMPANY

24 in. Wheel.

TWELVE BUCKETS.

TESTS OF WATER-WHEELS.

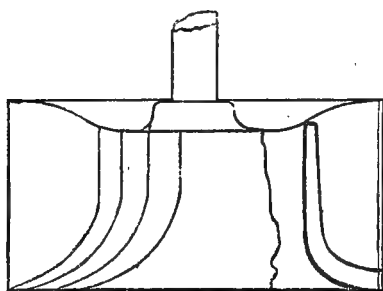
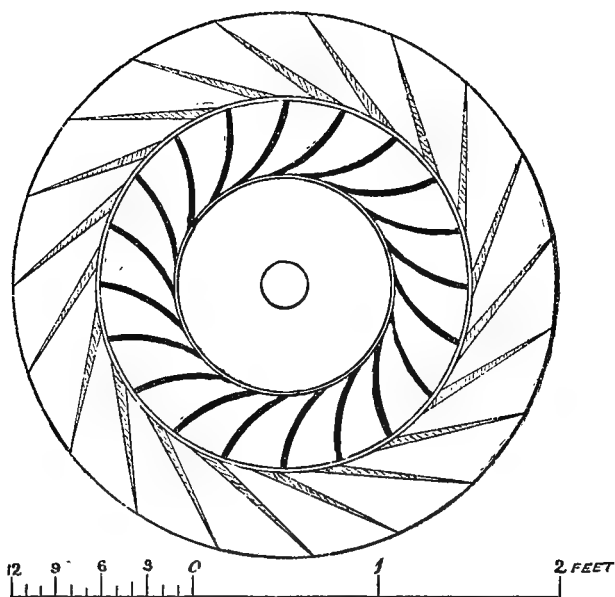
NOVEMBER 9, 1876. RODNEY HUNT, ORANGE, MASS. WHEEL 24 IN. DIAMETER.

NUMBER OF TEST.	TIME OF START.	TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
1	A.M. 9.27	A.M. 9.29	58	328	28.96	1.028	1817.08	76.096	99.46	76.6	.040	Full Gate.
2	9.38	9.39	62	317	29.26	1.034	1832.9	78.616	101.36	77.60	.040	"
3	P.M. 12.21	P.M. 12.23	55	300	29	1.040	1848.74	79.20	101.33	78.2	.040	"
4	12.28	12.30	68	300	29.47	1.045	1861.98	81.60	103.71	78.6	.040	"
5	12.33	12.34	70	295	29.75	1.047	1867.31	82.60	104.99	78.70	.040	"
6	12.35	12.36	72	276	29.25	1.038	1843.45	79.49	101.91	78.00	.040	"
7	12.40	12.42	40	312	30.25	.809	1270.6	49.92	72.64	68.72	.040	½ Gate.
8	12.43	12.45	42	300	30.27	.816	1284.1	50.40	73.46	68.60	.040	"
9	12.46	12.48	44	287.5	30.23	.820	1296.56	50.60	74.08	68.38	.040	"
10	12.50	12.52	54	306	29.80	.966	1656.2	66.096	93.28	71.00	.040	¾ Gate.
11	12.53	12.55	56	298	29.62	.973	1674.2	66.75	93.72	71.4	.040	"
12	12.56	12.58	58	289	29.60	.974	1676.7	67.05	93.80	71.4	.040	"
13	12.58'30"	12.59'30"	60	278	29.60	.974	1676.7	66.72	93.80	71.1	.040	"
14	1.03	1.05	36	223	30.45	.748	1129.63	32.11	65.01	49.2	.040	⅓ Gate.
15	1.07	1.09	34	238	30.44	.743	1118.27	32.37	64.34	50.3	.040	"
16	1.09	1.10	32	254	30.43	.742	1116	32.51	64.17	50.6	.040	"
17	1.11	1.12	30	266	30.50	.725	1077.84	31.92	62.13	51.3	.040	"

Very difficult to supply water at full gate. Head ran down several times, and tests were rejected.

Correct copy of notes.

SAMUEL WEBBER.



RODNEY HUNT (SWAIN BUCKET).

24 in. Wheel.

Number of buckets	20		
Number of shutes	19		
Least area of buckets	235	square inches.	
Shutes, area of entry	465.5	" "	
Shutes, area of discharge	133	" "	

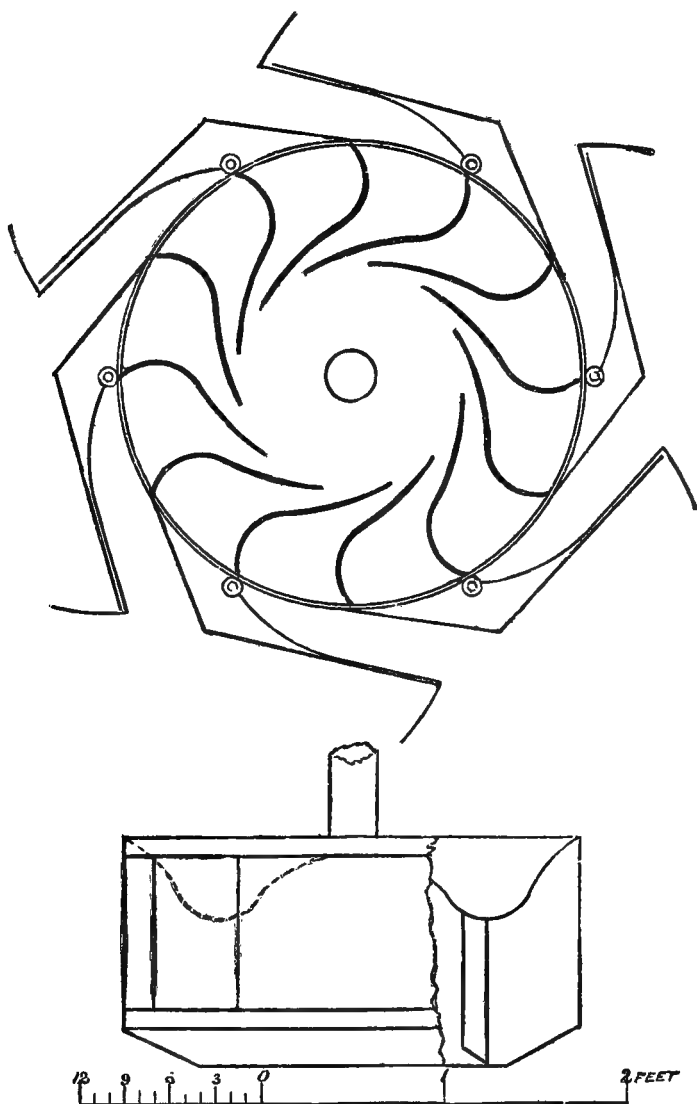
TESTS OF WATER-WHEELS.

NOVEMBER 10, 1876. STOUT, MILLS, & TEMPLE, DAYTON, OHIO. WHEEL 30 IN. DIAMETER.

NUMBER OF TEST.	TIME OF START.		TIME OF STOP.	WEIGHT LIFTED.	REVOLUTIONS PER MINUTE.	HEAD ON WHEELS.	HEAD ON WEIR.	CUBIC FEET DISCHARGED PER MINUTE.	HORSE-POWER OF WHEEL.	HORSE-POWER OF WATER.	PERCENTAGE OF EFFECT.	WASTE ON WEIR.	REMARKS, ETC.
	P.M.	P.M.											
1	4.42	4.44	64	245.5	30.05	.965	1653.53	62.848	93.91	66.9	.040		Full Gate.
2	4.45	4.47	66	236.5	29.70	.965	1653.53	62.436	92.82	67.2	.040		"
3	5.05	5.07	68	236	29.70	.975	1679.33	64.19	94.26	68.0	.040		"
4	5.08	5.10	70	231	29.55	.980	1692.38	64.68	94.52	68.4	.040		"
5	5.12	5.13	72	223	29.45	.983	1699.88	64.224	94.62	67.8	.040		"
6	5.19	5.20	74	210	29.05	.973	1674.2	62.16	91.92	67.8	.040		"
7	5.23	5.24	76	201	28.75	.978	1687	61.10	91.67	66.6	.040		"
8	5.28	5.29	46	259	29.80	.840	1344.2	47.656	75.71	62.8	.040		½ Gate.
9	5.41	5.42	50	252	29.70	.845	1356.2	50.40	76.13	66.20	.040		"
10	5.43	5.44	54	242	29.48	.854	1377.85	52.272	76.77	68.10	.040		"
11	5.45	5.46	58	230	29.38	.859	1389.93	53.36	77.18	69.13	.040		"
12	6.00'30"	6.01'30"	34	182	30.95	.548	706.24	24.752	41.31	59.91	.040		¼ Gate.
13	6.02'30"	6.03'30"	34	181	30.95	.547	704.28	24.616	41.18	59.77	.040		"
14	6.04'30"	6.05'30"	28	204	30.95	.535	680.96	22.848	39.83	57.4	.040		"
15	6.06'20"	6.07'20"	24	229	30.97	.527	665.55	21.984	38.96	56.4	.040		Gear on gate-shaft loose, and gate closed itself slowly.
16	6.08'30"	6.09'30"	24	224	30.98	.525	661.69	21.50	38.74	55.55	.040		

Correct copy of notes.

SAMUEL WEBBER.



STOUT, MILLS, & TEMPLE.

30 in. Wheel.

Number of buckets	12
Number of gates	6
Buckets, area of inlet	912 square inches.
Buckets, area of discharge	156 " "
Gates, area of inlet	300 " "

REPORTS ON AWARDS.

GROUP XX.

1. York Manufacturing Co., York, Pa., U. S.

TURBINE WATER-WHEELS.

Report.—Commended for good workmanship and utility as to the independent action of the gates.

2. Poole & Hunt, Baltimore, Md., U. S.

TURBINE WATER-WHEELS AND GEARING.

Report.—Commended for superior castings, good design, and excellent workmanship.

3. Wm. F. Mosser & Co., Allentown, Pa., U. S.

TURBINE WATER-WHEEL.

Report.—Commended for simplicity of design.

4. Bodine Manufacturing Co., Mount Morris, N. Y., U. S.

BRASS TURBINE WATER-WHEEL.

Report.—Commended for good workmanship.

5. Abraham N. Wolf, Allentown, Pa., U. S.

TURBINE WATER-WHEEL AND FLUME.

Report.—Commended for the simple and ingenious arrangement of the gates.

6. James Leffel & Co., Springfield, Ohio, U. S.

DOUBLE TURBINE WATER-WHEEL.

Report.—Commended for good design and workmanship, and good arrangement for the regulation of water.

7. T. H. Risdon & Co., Mount Holly, N. J., U. S.

TURBINE WATER-WHEEL.

Report.—Commended for efficiency as regards the arrangement of the guides and gates.

8. Thomas J. Alcott, Mount Holly, N. J., U. S.

TURBINE WATER-WHEEL.

Report.—Commended for ingenuity and good workmanship.

9. Knowlton & Dolan, Logansport, Ind., U. S.

TURBINE WATER-WHEEL.

Report.—Commended for good workmanship, and for a ratchet coupling designed to prevent breakage of gearing in the event of wheel becoming obstructed.

10. R. D. Wood & Co., Philadelphia, Pa., U. S.

TURBINE WHEELS.

Report.—Commended for good design of turbines, and excellent castings; the duplex turbine well calculated to produce efficiency for varying loads.

11. Silas Walton, Moorestown, N. J., U. S.

TURBINE WATER-WHEEL.

Report.—Commended for excellence of design as regards the coincident regulation of the guides and wheel buckets.

12. National Water-Wheel Co., Bristol, Conn., U. S.

TURBINE WATER-WHEELS.

Report.—Commended for ingenuity and good workmanship.

13. Lane Manufacturing Co., Montpelier, Vt., U. S.

TURBINE WATER-WHEEL.

Report.—The regulation of water is simple. The turbine is compact and of good workmanship.

14. Rodney Hunt Machine Co., Orange, Mass., U. S.

DOUBLE-ACTING TURBINE WATER-WHEEL.

Report.—Commended for simplicity, good workmanship, and adaptation of parts to produce efficiency.

15. John T. Noye & Son, Buffalo, N. Y., U. S.

TURBINE.

Report.—The workmanship is good. The guides and gates are well arranged and of simple design.

16. Springfield Iron Works, Springfield, Mo., U. S.

TURBINE WATER-WHEEL.

Report.—Commended for excellence of workmanship and of means for securing independent action of the gates.

17. Stout, Mills, & Temple, Dayton, Ohio, U. S.

TURBINE WHEELS.

Report.—Commended for very good workmanship, both as regards the turbines and the wrought-iron flume, and good design for the latter.

18. Stilwell & Bierce Manufacturing Co., Dayton, Ohio, U. S.

DOUBLE TURBINE WATER-WHEEL.

Report.—Commended for compactness, simplicity of construction, and good workmanship.

19. Fales & Jenks Machine Co., Pawtucket, R. I., U. S.

TURBINE.

Report.—Commended for good workmanship and tasty design.**20. N. F. Burnham, York, Pa., U. S.**

TURBINE.

Report.—Commended for good workmanship and simple and effective means for moving the gate.**21. James Haworth, Philadelphia, Pa., U. S.**

HYDRANT TURBINE.

Report.—This is a miniature, but complete, turbine of extreme simplicity of construction, and well adapted for furnishing power for family sewing machines or light household or manufacturing work.**22. Edward Sawyer, Boston, Mass., U. S.**

DRAWINGS OF BOYDEN FOURNEYRON TURBINE.

Report.—The drawings show that great pains have been taken to design the curves and found the proportions on careful investigations of the principles involved, as modified by the conditions of practice; and the high results obtained, as ascertained by legal investigation, may be properly considered a brilliant and very useful triumph of applied science.**23. Stokes & Parrish, Philadelphia, Pa., U. S.**

ONE PASSENGER ELEVATOR OF THE LARGEST CLASS.

Report.—Commended for good design and workmanship; carefully studied details to prevent accidents.**24. Otis Brothers & Co., New York, N. Y., U. S.**

PASSENGER ELEVATOR.

Report.—Commended for good adaptation to purpose intended, and good workmanship; attentive consideration to details relating to safety.**25. Carlile & Elliott, Steubenville, Ohio, U. S.**

SAFETY LOCK FOR ELEVATORS.

Report.—Commended for ingenuity, invention, simplicity, and efficiency.**26. Joseph Goldmark, New York, N. Y., U. S.**

SAFETY ELEVATORS FOR HOTELS.

Report.—Commended for originality, ingenuity, and efficiency for the intended purpose.**27. Mathias Pennypacker, Philadelphia, Pa., U. S.**

HAND-HOISTING MACHINE.

Report.—The exhibit is an example of chain hoisters with a cased endless or tangent screw for operating main chain drums. The apparatus is well made and operates efficiently.

28. Tatham & Brothers, New York, N. Y., and Philadelphia, Pa., U. S.

SAFETY APPARATUS FOR HOISTING MACHINES.

Report.—Commended for ingenuity and utility.

29. J. R. Ritter, Reading, Pa., U. S.

HYDRAULIC HOISTING APPARATUS.

Report.—The models exemplify ingenious and useful adaptations and combinations of hydraulic and wire rope hoisting apparatus.

30. United States Hoisting & Conveying Co., New York, N. Y., U. S.

HOISTING AND CONVEYING APPARATUS.

Report.—The apparatus is very ingenious, and quite simple in construction and operation. With it buckets of minerals or packages of goods are hoisted, transported to a distance, and then, at will, either dumped or lowered into position with such certainty and rapidity as to effect a very important saving in the cost of doing this kind of work.

31. George C. Howard, Philadelphia, Pa., U. S.

HOISTING MACHINE.

Report.—Commended for ingenuity and fitness for the intended purpose.

32. Yale Lock Manufacturing Co., Stamford, Conn., U. S.

SAFETY HOISTING MACHINE..

Report.—These exhibits by the Yale Lock Manufacturing Co. are of good workmanship. The inventions embodied therein are very meritorious and useful.

33. Volney W. Mason & Co., Providence, R. I., U. S.

ELEVATOR HOISTING MACHINE AND SAFETY PLATFORM.

Report.—Commended for compactness and well-studied details.

34. Leopold Sternberger, Philadelphia, Pa., U. S.

SAFETY SCREW STEAM PLATFORM ELEVATOR.

Report.—This design for a screw elevator is, so far as can be ascertained from the model, well calculated to promote safety.

35. Otis Brothers & Co., New York, N. Y., U. S.

FURNACE ENGINE FOR HOISTING PURPOSES.

Report.—This is an engine especially designed for elevating the charges to blast-furnaces and for hoisting work of similar character. It is a substantial and excellent engine, provided with special appliances adapting it to this service.

36. Lidgerwood Manufacturing Co., New York, N. Y., U. S.

ROTARY HOISTING AND ELEVATING ENGINES.

Report.—The engines exhibited are of a compact design, and have only a few movable parts, wherefore they can be useful in such cases where small power is desired, not regularly, but only from time to time.

37. James Bates, Baltimore, Md., U. S.

HAND ELEVATORS.

Report.—The exhibit is a good example of its class.

38. S. S. Williams & Co., Philadelphia, Pa., U. S.

HOD ELEVATOR.

Report.—Commended for simplicity and fitness for its intended purpose.

39. J. B. Sweetland, Pontiac, Mich., U. S.

HOD ELEVATOR.

Report.—A good exhibit of its class, simple and strong.

40. Locke & Colt, Washington, D. C., U. S.

DAVIS ELEVATING SIGNAL TOWER.

Report.—The exhibit consists of a series of telescopic iron tubes arranged to be closed together and carried on a road wagon. It is provided with base-piece, elevating apparatus, and guys, so that the tubes may be extended vertically and form the support for an elevated platform, reached by a rope ladder or hand elevator. The details have been well carried out to secure lightness, portability, and facility of operation, with sufficient strength for the purpose; and the apparatus is well fitted for serviceable and convenient use as a temporary signal station for surveying or military purposes.

41. Shive Governor Co., Bethlehem, Pa., U. S.

GOVERNOR AND MOTOR.

Report.—The governors exhibited in different sizes show the well-studied novelty of stopping the engine in case the governor's driving-belt should break or leave the pulley.

42. Wm. Farr Goodwin, Stelton, N. J., U. S.

MECHANICAL MOVEMENT.

Report.—This is a very ingenious plan for producing reciprocating from rotary motion by means of an intermediate disk serrated on its sides, which, being held to prevent rotation, is forced to vibrate in the direction of the axis of the shaft by engaging with similar serrations on two contiguous revolving disks. With the large surfaces running in oil, as provided to secure durability, in connection with the rubber buffers to reverse direction, the movement, from its simplicity, is capable of a number of useful applications, and has been applied to mowers and reapers.

43. La France Manufacturing Co., Elmira, N. Y., U. S.

ROTARY PUMPS AND ENGINE.

Report.—The exhibit is a good example of its class.

44. W. W. Grier, Hulton, Pa., U. S.

HYDRAULIC RAM SENTINEL.

Report.—Commended for ingenuity, utility, and efficiency.

45. Hilborne L. Roosevelt, New York, N. Y., U. S.

HYDRAULIC AUTOMATIC ORGAN BLOWER.

Report.—Commended for extreme simplicity and efficiency.

46. Bagley & Sewall, Watertown, N. Y., U. S.

METAL FORCE PUMP WITH SELF-PACKING JOINTS.

Report.—A novel and good example of rotary pump.

47. Bolen, Crane, & Co., Newark, N. J., U. S.

COMPOUND HYDRAULIC PRESS.

Report.—Commended for invention, simplicity, efficiency, and cheapness.

48. Hydrostatic and Hydraulic Co. of Pennsylvania, Philadelphia, Pa., U. S.

COMPOUND PROPELLER PUMP FOR QUARRIES AND MINES, ETC.

Report.—The pump is simple, operates well, has direct passages, and no valves.

49. Lane Brothers, Millbrook, Dutchess Co., N. Y., U. S.

HYDRAULIC MOTOR FOR SEWING MACHINES.

Report.—Commended for good adaptation to the purpose intended, and economy and simplicity of construction.

50. Albert G. Buzby, Philadelphia, Pa., U. S.

WATER MOTOR FROM HYDRANT PRESSURE.

Report.—Commended for good workmanship, simplicity of construction, and facility of application.

51. The Gould's Manufacturing Co., Seneca Falls, N. Y., U. S.

HAND AND POWER PUMPS AND HYDRAULIC RAMS.

Report.—Commended for the large, attractive, and highly creditable display of tastily designed and very well constructed iron and brass hand and force pumps and hydraulic rams adapted to various uses.

52. A. Gawthrop & Son, Wilmington, Del., U. S.

GLASS MODELS OF HYDRAULIC RAMS WITH REGULATORS IN OPERATION.

Report.—The automatic regulator is useful and efficient. The double ram enables a small supply of good water to be lifted with any other water available.

53. James Eccles, Philadelphia, Pa., U. S.

QUADRUPLE SCREW POWER PRESS; PIVOT CENTRE FOR DRAWBRIDGE.

Report.—A well-made screw press of convenient form.

An ingenious and useful pivot centre for drawbridges.

54. H. Belfield & Co., Philadelphia, Pa., U. S.

VALVES, COCKS, AND GAUGES.

Report.—This exhibit comprises a large variety of valves, cocks, water-gauges, and other apparatus of steam engines and boilers. Of good design, best materials, and are thoroughly well made; an exhibit highly creditable to the manufacturer.

55. George R. Kirk, Philadelphia, Pa., U. S.

BRASS VALVES AND COCKS.

Report.—Commended for good workmanship and material.

56. Dennis Long & Co., Louisville, Ky., U. S.

IRON GAS AND WATER PIPES.

Report.—Commended for good standard workmanship and material.

57. Cooper, Jones, & Cadbury, Philadelphia, Pa., U. S.

PUMPS, BRASS VALVES AND COCKS.

Report.—Commended for fine exhibit, good workmanship and material.

58. Murrill & Keizer, Baltimore, Md., U. S.

GAUGE COCKS.

Report.—Commended for a simple arrangement well adapted for the purpose intended.

59. Vulcanized Fibre Co., Wilmington, Del., U. S.

PIPES.

Report.—A good, strong exhibit of its class.

60. W. C. Allison & Co., Philadelphia, Pa., U. S.

BOILER TUBES, OIL WELL TUBING, AND STEAM PIPES.

Report.—A good exhibit of its class, of best workmanship and material; the pipe connection a very meritorious invention.

61. Bridgewater Iron Co., Bridgewater, Mass., U. S.

SEAMLESS COPPER AND BRASS TUBES.

Report.—Commended for manufacture of the best material; excellent workmanship.

62. Evans, Dalzell, & Co., Pittsburg, Pa., U. S.

BOILER, OIL WELL, ARTESIAN, AND HYDRAULIC TUBING, AND WROUGHT-IRON PIPES.

Report.—Commended for good material and workmanship; solid, and well adapted for the purpose intended.

63. Benedict & Burnham, Waterbury, Conn., U. S.

SEAMLESS COPPER AND BRASS TUBES.

Report.—Commended for first-class work and material.

64. Peet Valve Co., Boston, Mass., U. S.

BRASS AND IRON STEAM VALVES.

Report.—A fair exhibit; good workmanship and material.**65. Colwell Lead Co., New York, N. Y., U. S.**

LEAD PIPES, BLOCK TIN, AND TIN-LINED LEAD PIPE.

Report.—Commended for durability, cleanliness, and strength.**66. R. J. Houghton, New York, N. Y., U. S.**

BOILER AND TUBE COMPOUND FOR REMOVING AND PREVENTING SCALE.

Report.—Meritorious invention; efficient in action, and well adapted for the purpose intended.**67. Gloucester Iron Works, Gloucester City, N. J., U. S.**

CAST-IRON PIPES, FIRE HYDRANTS, AND STOP VALVES.

Report.—A good exhibit of its class; good workmanship and material.**68. Howard Safety Boiler Manufacturing Co., Boston, Mass., U. S.**

SAFETY SECTIONAL WROUGHT-IRON NINE-INCH TUBE BOILER.

Report.—Commended for strength and good circulation.**69. C. W. & H. W. Middleton, Philadelphia, Pa., U. S.**

IRON TUBES, BRASS COCKS AND VALVES.

Report.—Commended for good standard workmanship.**70. Morris, Tasker, & Co. (Limited), Philadelphia, Pa., U. S.**

WROUGHT-IRON TUBES, TOOLS, AND BRASS WORK.

Report.—Commended for first-class standard work, great variety, best execution and material.**71. Henry S. Lansdell & John S. Leng, New York, N. Y., U. S.**

LEVER AND CAM VALVES AND SIPHON PUMP.

Report.—This is a straight-way valve of a new and admirable design.

The siphon pump, working by direct action of steam, combines simplicity and durability with cheapness.

72. Warren Foundry & Machine Co., Phillipsburg, N. J., U. S.

GAS AND WATER PIPES.

Report.—Commended for good workmanship and material.**73. Stanley G. Flagg & Co., Philadelphia, Pa., U. S.**

FITTINGS FOR GAS, STEAM, AND WATER PIPES.

Report.—Commended for good cast, material, and workmanship.**74. Jesse W. Starr & Son, Camden, N. J., U. S.**

GAS AND WATER PIPES, STOP VALVES, AND FIRE-HYDRANT CASTINGS.

Report.—Commended for great variety, good casts and material.

75. National Tube Works Co., Boston, Mass., U. S.

IRON BOILER TUBES, IRON HYDRAULIC, STEAM, GAS, WATER, AND SEWAGE PIPES; ANNEALED PIPE.

Report.—This is an exhibit of a character calling for especial commendation. While the quality of the work shown is uniformly of the highest excellence, the range of achievement marks a decided advance in this branch of manufacture. Commended also for a very superior and extended exhibit of not only uncommonly large pipes, but of pipes large in size and of great thickness; and for superior light-thickness pipes and tubes for oil wells.

76. Jarecki Manufacturing Co., Erie, Pa., U. S.

VALVES AND COCKS.

Report.—Commended for a good exhibit, in workmanship and material.

77. Levi F. Smith, Philadelphia, Pa., U. S.

BOILER TRY COCKS.

Report.—This is an original and admirable improvement on the ordinary form of this attachment to boilers.

78. B. E. Lehman, Bethlehem, Pa., U. S.

GAUGE COCKS, WATER GAUGES, OIL CUPS, AND GATE VALVES.

Report.—The implements exhibited are of a solid character of construction and very good workmanship, and are in a high degree fit for the purpose intended.

79. Sulzer Brothers, Winterthur, Zurich, Switzerland.

A NEW SYSTEM OF REVERSING GEAR FOR STEAM ENGINES.

Report.—The combinations of the reversing gear of steam engines using steam expansively, as presented in the model, fully effect their object.

80. Melvin Stephens, New York, N. Y., U. S.

CEMENT-LINED WROUGHT-IRON WATER PIPE.

Report.—A good exhibit of durable and cheap and effective water pipes.

81. Mohawk & Hudson Manufacturing Co., Waterford, N. Y., U. S.

STRAIGHT-WAY VALVES; FIRE AND GARDEN HYDRANTS.

Report.—Fair specimens of work and design.

82. Merchant & Co., Philadelphia, Pa., U. S.

SEAMLESS BRASS AND COPPER TUBES.

Report.—Commended for good workmanship and material.

83. Walworth Manufacturing Co., Boston, Mass., U. S.

STEAM COCKS AND VALVES.

Report.—Commended for good workmanship and material.

84. Ludlow Valve Manufacturing Co., Troy, N. Y., U. S.

SLIDING STOP VALVES; FIRE HYDRANTS.

Report.—Commended as excellent in design, workmanship, and material.**85. William Radde, New York, N. Y., U. S.**

GLASS-LINED IRON PIPES AND FITTINGS.

Report.—Commended as a good invention and well adapted for the purpose designed.**86. Andrew O'Neil, Ansonia, Conn., U. S.**

WATER AND GAS PIPES; FIRE HYDRANT.

Report.—A very meritorious invention, combining cheapness in construction, facility of manipulation in laying and making the joints, saving of time and material.**87. McNab & Harlin Manufacturing Co., New York, N. Y., U. S.**

VALVES, COCKS, WHISTLES, AND WATER GAUGES.

Report.—The exhibit of valves, cocks, water gauges, lubricators for shafts and steam cylinders, hose couplings, is not only very complete in respect to the different sizes, but is at the same time of excellent material and workmanship.**88. Eaton, Cole, & Burnham Co., New York, N. Y., U. S.**

STEAM VALVES, WATER COCKS, HOSE NOZZLES.

Report.—Good exhibit, excellent workmanship; the contracting nozzle worthy of special notice.**89. Union Water Meter Co., Worcester, Mass., U. S.**

STEAM WHISTLE.

Report.—Commended for its high degree of efficiency after many days' performance.**90. Lang & Ogden, New York, N. Y., U. S.**

LEVER AND CAM GATE VALVES.

Report.—Light and quick in action, giving a clear opening; good material and workmanship.**91. Toledo Pump Co., Toledo, Ohio, U. S.**

WOODEN PUMPS.

Report.—Commended for good workmanship, careful selection and preparation of material, durability by use of thin metal expanding linings, and by enamel linings screwed in.**92. Byrns & Bryan, New York, N. Y., U. S.**

ALE PUMP COMBINED WITH COOLING APPARATUS.

Report.—Commended for elegant design and workmanship, and cleanliness; well designed for the purpose intended.**93. Wm. D. Andrews & Brother, New York, N. Y., U. S.**

ELEVATOR.

Report.—Commended for ingenuity of the elevator as to the arrangement of gearing for engine and the safety device on car; good design, and well-studied details for preventing accidents

94. Wm. D. Andrews & Brother, New York, N. Y., U. S.

CENTRIFUGAL PUMPS.

Report.—Commended for the well-established excellence of the original pump, and the simplicity of the newly-designed pump.

95. Heald, Sisco, & Co., Baldwinsville, N. Y., U. S.

CENTRIFUGAL PUMPS.

Report.—Commended for simplicity, compactness, efficiency, and good workmanship.

96. W. H. Harrison, Philadelphia, Pa., U. S.

DOUBLE-ACTING TWO-VALVE PUMP.

Report.—Commended for compactness and utility.

97. Chapman Valve Manufacturing Co., Boston, Mass., U. S.

WATER, GAS, AND STEAM VALVES.

Report.—A good exhibit of its class; good workmanship, and easy manipulation.

98. Wm. P. Uhlinger, Philadelphia, Pa., U. S.

CENTRIFUGAL HYDRO EXTRACTOR.

Report.—Commended for simplicity, efficiency, and good substantial work.

99. Thomas Shaw, Philadelphia, Pa., U. S.

VACUUM GAUGES, TEST PUMPS, AIR-CHAMBER FEEDERS, AND HYDRAULIC STOP VALVE.

Report.—Test pump and gauge of the most simple construction and most reliable character; are worthy of especial mention.

Cushion-seated valve well constructed, and well adapted for rapid motion.

100. American Tube Works, Boston, Mass., U. S.

SEAMLESS DRAWN BRASS AND COPPER TUBES, TAPER TUBES.

Report.—Commended for great variety, excellent workmanship and material.

101. Fred. Lunkenheimer, Cincinnati, Ohio, U. S.

LUBRICATORS, OIL CUPS, UNTRIMMED CASTINGS, AND STEAM VALVES.

Report.—Commended for good casts and well-finished workmanship.

102. Schutte & Goehring, Philadelphia, Pa., U. S.

KORTING'S PATENT STEAM JETS.

Report.—Commended for good design and workmanship.

103. J. W. Connery, Philadelphia, Pa., U. S.

CONCAVE CALKING FOR STEAM BOILERS, IRON SHIPS, AND VESSELS.

Report.—This system is an unquestionable improvement over the old mode of calking riveted joints, adding especially to the value, durability, and safety of steam boilers.

104. Peck Brothers & Co., New Haven, Conn., U. S.

HOSE NOZZLES AND BRASS WATER-COCKS.

Report.—Commended for good exhibit and good workmanship.

105. Coffin & Woodward, Boston, Mass., U. S.

SHIP PUMPS.

Report.—The pumps are excellently designed and constructed, and well adapted for the purpose intended.

106. George Draper & Son, Hopedale, Mass., U. S.

SELF-LUBRICATING BOX.

Report.—Commended for novelty and simplicity.

107. White, Clark, & Co., Baldwinsville, N. Y., U. S.

CENTRIFUGAL PUMP.

Report.—A well-made example of this class of pump.

108. Philadelphia Hydraulic Works, Philadelphia, Pa., U. S.

STEAM PUMP.

Report.—Commended for good construction and great facility for examination of pump valves.

109. Cook & Pulver, New York, N. Y., U. S.

LUBRICATING CUPS.

Report.—A good and meritorious style of lubricating cup.

110. Hartford Pump Co., Hartford, Conn., U. S.

COMPRESSED AIR-PUMP.

Report.—Commended for ingenuity of construction, and utility in enabling wind power to be transmitted to a distance.

111. Lang & Ogden, New York, N. Y., U. S.

SIPHON PUMP.

Report.—A meritorious invention of its class, efficient in action, giving a clear opening, and not liable to clog.

112. Aultman, Miller, & Co., Akron, Ohio, U. S.

SELF-REGISTERING DYNAMOMETER.

Report.—This instrument is well adapted for measuring direct pulls by means of a double elliptic spring with simple recording apparatus attached. It is very compact, neatly finished, and well designed for the purposes intended.

113. Wickersham & Brother, Philadelphia, Pa., U. S.

OIL CUPS AND FEEDERS.

Report.—Commended for excellence of construction and reliability of action.

114. Philips & Coats, St. Louis, Mo., U. S.

PATENT SECTIONAL HYDRANT.

Report.—A good specimen of its class; a meritorious improvement.

115. Schutte & Goehring, Philadelphia, Pa., U. S.

PUMPS.

Report.—Commended for excellence of design and workmanship, and accessibility for examination and repairs.

116. William Young, Easton, Pa., U. S.

DEEP-WELL PUMP AND STANDARDS.

Report.—Commended for the tastily-designed and durable combination of gas-pipe, pipe fittings, and special castings, to form a deep-well pump standard.

117. Chard & Howe, New York, N. Y., U. S.

LUBRICATING CUP AND COMPOUND.

Report.—An adjustment that enables any desired degree of friction to be obtained on the end of copper rods.

118. Henry C. Haskell, Albany, N. Y., U. S.

WATER MOTORS.

Report.—The engines exhibited are of simple and reliable construction, and well fitted for cases in which small amounts of power are occasionally required.

119. W. & B. Douglas, Middletown, Conn., U. S.

HAND AND POWER PUMPS; HYDRAULIC RAMS.

Report.—Commended for the large, attractive, and excellent display of tastily-designed hand and power pumps; and hydraulic rams adapted to various uses.

120. Nichols, Harris, & Walker, New London, Conn., U. S.

ACID PUMP AND SIPHON.

Report.—Commended for the ingenuity displayed in the design, and utility for the particular purpose.

121. C. W. King, Boston, Mass., U. S.

FORCE AND HOUSE PUMPS.

Report.—The exhibits are good examples of their class.

122. Rumsey & Co., Seneca Falls, N. Y., U. S.

PUMPS AND HYDRAULIC RAMS.

Report.—Commended for the large and excellent display of well-made pumps adapted to various uses.

123. John Robertson & Co., Brooklyn, N. Y., U. S.

HYDRAULIC PUMPS AND PRESSES.

Report.—Commended for very good workmanship, good design, and details carefully considered.

124. Union Manufacturing Co., New Britain, Conn., U. S.

HAND AND POWER PUMPS, HYDRAULIC RAMS, AND GARDEN ENGINES.

Report.—The exhibits are good examples of their class.**125. B. F. Biggs & Wells, Lafayette, Ind., U. S.**

WOODEN LIFTING AND SUCTION PUMP.

Report.—Good example of the ordinary form of wooden pumps.**126. Henry Chapman, Philadelphia, Pa., U. S.**

CENTRIFUGAL WATER EXTRACTOR.

Report.—Commended for efficiency and good substantial work.**127. Oscillating Pump Co., Philadelphia, Pa., U. S.**

FORCE AND BILGE HAND PUMPS, HAND FIRE ENGINES.

Report.—Commended for simplicity, cheapness, and efficiency.**128. Richard Dudgeon, New York, N. Y., U. S.**

HYDRAULIC JACKS, PUNCHES, AND BOILER-TUBE EXPANDERS.

Report.—The lifting and pulling jacks and punches exhibited are of excellent construction and of great usefulness for the purposes intended.**129. The Chalmer Spence Co., New York, N. Y., U. S.**

COMPOSITION BOILER AND STEAM PIPE COVERING.

Report.—This is undoubtedly a valuable protection against radiation of heat, although, in the absence of a test, the precise degree of its efficiency cannot be determined.**130. F. L. & W. Spiess, New York, N. Y., U. S.**

BELT CLAMP.

Report.—Commended for very simple, convenient, and useful adaptation of the principles of the pulley to the tightening of belt clamps.**131. Ewart Manufacturing Co., Chicago, Ill., U. S.**

DETACHABLE DRIVE CHAIN.

Report.—Commended for ingenuity, efficiency, and utility.**132. W. P. Powers, La Crosse, Wis., U. S.**

WIRE BELTING.

Report.—Commended for ingenuity, durability, and efficiency.**133. Josiah Gates & Sons, Lowell, Mass., U. S.**

LEATHER HOSE AND BELTING.

Report.—The leather hose is a good exhibit of its class, of good material and workmanship. Commended for an exhibit of excellent samples of well-finished and well-constructed leather belting; also for very good lace and apron leather.

134. Chartfield, Underwood, & Co., New York, N. Y., U. S.

ANGULAR BELTING.

Report.—The construction gives sufficient adhesion with comparatively narrow widths, and permits ready changes of direction.

135. Anton Heim, New York, N. Y., U. S.

LEATHER BELTING.

Report.—Commended for a fine display of leather belting, of good material, well constructed and finished.

136. A. Burgess & Son, Providence, R. I., U. S.

LEATHER BELTING.

Report.—Commended for the exhibit of specimens of excellently-constructed leather belting.

137. Thomas J. Rorer, Philadelphia, Pa., U. S.

LEATHER BELTING.

Report.—Commended for the exhibit of flexible and well-made specimens of combined leather and canvas belting, well calculated for very efficient service in dry locations.

138. J. B. Hoyt & Co., New York, N. Y., U. S.

LEATHER BELTING.

Report.—Commended for the fine exhibit of superior leather belting, of well-established excellence in workmanship and material, and made from selected hides tanned with oak bark by the exhibitors.

139. New York Belting & Packing Co., New York, N. Y., U. S.

RUBBER BELTING, PACKING, AND HOSE.

Report.—These exhibits are first-class of their kind in every respect.

140. Charles A. Schieren, New York, N. Y., U. S.

LEATHER BELTING.

Report.—Commended for the exhibit of specimens of leather belting, of excellent material and workmanship.

141. P. Jewell & Son, Hartford, Conn., U. S.

LEATHER BELTING AND METALLIC-TIPPED LACES.

Report.—Commended for the exhibit of excellent specimens of well-constructed leather belting, made from leather tanned with hemlock and oak bark by the exhibitors; also for the very convenient and serviceable metallic-tipped belt lacings.

142. Page Belting Co., Concord, N. H., U. S.

LEATHER BELTING.

Report.—Commended for the exhibit of good examples of pliable, well-constructed belts, from leather tanned by the exhibitor with hemlock bark and muriate of tin.

143. E. B. Richie, Philadelphia, Pa., U. S.

LEATHER BELTING, HOSE, AND TANNED HIDES.

Report.—Commended for the exhibit of an excellent display of belting and hose, and of superior tanned hides suitable for the manufacture of hose.

144. Alexander Brothers, Philadelphia, Pa., U. S.

LEATHER BELTING.

Report.—Commended for the exhibit of specimens of excellently-constructed and finely-finished leather belting.

145. H. L. Fairbrother & Co., Pawtucket, R. I., U. S.

LEATHER BELTING.

Report.—Commended for the exhibit of a good display of belting suitable for use in dry locations, made from leather tanned with gambia by the exhibitors.

146. Branch, Crookes, & Co., St. Louis, Mo., U. S.

ADJUSTABLE COUNTERSHAFT, HANGER, AND BELT TIGHTENER.

Report.—The exhibit is novel in form, neat in design, and effective in operation.

147. George C. Howard, Philadelphia, Pa., U. S.

BELT GEARING FOR SEWING MACHINES.

Report.—Commended for simplicity and utility.

148. Crane Brothers, Westfield, Mass., U. S.

JAPANESE PAPER BELTING.

Report.—The paper belting possesses considerable tensile strength and a fair degree of pliability. The exhibit shows that belts can be cheaply made of paper, though their value for extended use is not yet demonstrated.

149. Jerome Wheelock, Worcester, Mass., U. S.

STEAM ENGINE PISTON PACKING.

Report.—Commended for its efficient and durable character.

150. Jerome Wheelock, Worcester, Mass., U. S.

AUTOMATIC CUT-OFF ENGINE.

Report.—Commended for the simplicity of the mechanism by means of which the variable cut-off is effected; and for general good construction.

151. C. H. Brown & Co., Fitchburg, Mass., U. S.

STEAM ENGINE.

Report.—The engine exhibited in the performance of driving the saw-mill has a highly elegant design, solid and reliable construction, and first-class workmanship. The valve gear and automatic regulation, giving the trip cut-off, acts in the most exact manner, and gives in no one point occasion for unusual wear. The action of the steam, as shown by indicator diagrams, is satisfactory.

152. Chas. W. Ervien & Brothers, Philadelphia, Pa., U. S.**HORIZONTAL AND VERTICAL STEAM ENGINES.**

Report.—These engines are of elegant design and finish.

153. Weimar Machine Works, Lebanon, Pa., U. S.**HIGH-SPEED BLOWING ENGINE.**

Report.—Compact and substantially-built engine; of good material and workmanship, and especially commended for the peculiar design of the air valves, well adapted for quick motion.

154. Robt. Wetherill & Co., Chester, Pa., U. S.**STEAM ENGINE WITH SELF-PACKING PISTON.**

Report.—They exhibit a stationary steam engine, on the Corliss plan, having its piston self-packed, which is, in materials, proportions, and workmanship, of the first class.

155. T. Wilbraham & Brother, Philadelphia, Pa., U. S.**PRESSURE BLOWERS AND GAS EXHAUSTERS.**

Report.—Commended for good design and materials; very efficient in action, with the special advantage that they can be connected for motion directly with the engine without the use of gearing or belting.

156. H. & F. Blandy, Zanesville, Ohio, U. S.**PORTABLE, AGRICULTURAL, SAW-MILL, AND STATIONARY ENGINES.**

Report.—Commended in that this exhibit of engines, stationary and portable, is one of great merit; that the plan makes the heater the bed-plate of the engine; that in plan, proportions, materials, and workmanship the engines are of the first class.

157. George J. Wardwell, Rutland, Vt., U. S.**STATIONARY AND PORTABLE VALVELESS STEAM ENGINE.**

Report.—This is an ingenious engine, in which the piston is, by being rotated in opposite directions alternately through an arc corresponding with the arc of vibration of the connecting-rod, made to perform the functions of a valve, while the connecting-rod and crank are retained, as in ordinary engines. The engine runs well, makes a good diagram, and can be constructed to cut the steam off at any fixed point between the commencement and half stroke.

158. B. F. Sturtevant, Boston, Mass., U. S.**FAN BLOWERS.**

Report.—Commended for a splendid exhibit; great variety, good workmanship and materials.

159. H. R. Worthington, New York, N. Y., U. S.**STEAM PUMPING ENGINES.**

Report.—The duplex system of pumps, patented by Henry R. Worthington, is of well-established excellence, and is considered a positive advance in the art of moving water under pressure by means of pistons. The system permits of remarkable simplicity of construction, and insures smoothness of working, efficiency of action, and reliability for extended use, whatever the pressure or length of the water column, or the size of the apparatus employed. For pumping engines, compound steam cylinders are provided, to secure economy of fuel.

160. Sample, McElroy, & Co., Keokuk, Iowa, U. S.

SEMI-PORTABLE VERTICAL STEAM ENGINE AND BOILER.

Report.—Commended for having exhibited a series of small steam engines of very good workmanship, to be used where small power is required regularly, for which purpose the engines are very well fitted.

161. P. H. & F. M. Roots, Connersville, Ind., U. S.

ROTARY PRESSURE BLOWERS, HAND BLOWERS, AND GAS EXHAUSTER.

Report.—A good exhibit of the machines mentioned; well designed, good workmanship and materials; very efficient.

162. Charles C. Klein, Philadelphia, Pa., U. S.

ECCENTRIC PISTON ENGINES.

Report.—The engines exhibited are of compact design, and have a few movable parts; they are of good workmanship and run very smoothly, being therefore useful in such cases where small power is required not continually but from time to time.

163. Frick & Co., Waynesboro', Pa., U. S.

STATIONARY ENGINES.

Report.—The engines exhibited are of a very good design and good workmanship, being well fitted for the purpose intended.

164. Hartford Foundry and Machine Co., Hartford, Conn., U. S.

AUTOMATIC AND VARIABLE CUT-OFF NON-CONDENSING STEAM ENGINE.

Report.—The engine exhibited, being in work for driving the shafting of a workshop, is of simple and substantial construction, and possesses a very simple and convenient cut-off mechanism regulated by the governor.

165. Buckeye Engine Co., Salem, Ohio, U. S.

AUTOMATIC CUT-OFF AND THROTTLING STEAM ENGINES.

Report.—We regard this as in all respects an excellent engine, well designed, excellently made, cutting off the steam by a very well arranged mechanism, and under complete control of the governor, and running very smoothly.

166. E. A. L. Roberts, Titusville, Pa., U. S.

STEAM ENGINE.

Report.—Commended for an excellent method of forming and securing in its place the crank-pin of double crank engines.

167. New York Safety Steam Power Co., New York, N. Y., U. S.

LAUNCH ENGINES, STATIONARY ENGINE, COMBINED ENGINE AND BOILER.

Report.—The engines, vertical and horizontal, of various sizes, stationary and portable, and the vertical boilers exhibited, are, in plans, proportions, materials, and workmanship, of a high order of excellence. The working parts, being severally machine-made duplicates, have the interchangeable character of value in construction and repair. The designs present instruments of steam power agreeable to the eye.

168. Cornell University Machine Shop, Ithaca, N. Y., U. S.

STEAM ENGINE.

Report.—The engine, lathe, and other products exhibited as the work of the students of the Cornell University are highly creditable to taught and teacher.

The engine, in which provision is made for the use of steam expansively by balanced valve gear regulated by governor, presents evidence in the plan that the strains of power developed have been carefully studied, and in the workmanship, that truth and accuracy are the essential considerations.

169. John F. Haskins, Philadelphia, Pa., U. S.

INTERCHANGEABLY MADE STEAM ENGINES.

Report.—These engines are made of such a design and their parts shaped in a way to allow them to be finished on tools and by gauges, this having been the process of executing them.

170. Baird & Huston, Philadelphia, Pa., U. S.

STEAM ENGINE.

Report.—A very well designed and well executed engine with boiler, erected in a yacht, being in a high degree adapted for the purpose intended.

171. Isaac W. Forbes, Chicago, Ill., U. S.

STEAM ENGINE VALVES AND GEAR.

Report.—This is a novel and ingenious arrangement, and, where simplicity is the principal object, will be useful in many situations.

172. The Lane & Bodley Co., Cincinnati, Ohio, U. S.

STEAM ENGINE FOR DRIVING SAW-MILL.

Report.—The engine is of elegant design and very good workmanship, neglecting in no point the solid character required for the purpose intended.

173. Griffith & Wedge, Zanesville, Ohio, U. S.

VERTICAL PORTABLE ENGINE.

Report.—Commended for having exhibited a portable engine with vertical cylinder and horizontal boiler, both of excellent workmanship; the engine is of best design and construction; the difficulties of uniting the vertical engine with the horizontal boiler are overcome in a good way.

174. Exeter Machine Works, Boston, Mass., U. S.

PRESSURE BLOWERS, FAN BLOWERS, AND EXHAUST FANS.

Report.—Well adapted for the purpose intended; good workmanship.

175. E. D. Leavitt, Cambridgeport, Mass., U. S.

DRAWING OF LAWRENCE PUMPING ENGINES.

Report.—The general design is artistic, and very creditable engineering skill is shown in the excellent selection, combinations, and proportions of parts designed to secure economy in the use of steam.

176. Burleigh Rock Drill Co., Fitchburg, Mass., U. S.

AIR COMPRESSOR.

Report.—Commended for a good exhibit of its class, good workmanship and material, good arrangement.

177. Boston Hydraulic Motor Co., Boston, Mass., U. S.

HYDRAULIC AUTOMATIC ORGAN BLOWER.

Report.—Commended for good design and construction.

178. Wells Balance Engine Co., New York, N. Y., U. S.

DOUBLE PISTON ENGINE.

Report.—The engine exhibited tries to realize high speed for the piston, and is successful in this to a certain limit. The workmanship is good and the construction reliable.

179. Ferrell & Jones, Philadelphia, Pa., U. S.

COMBINED ENGINE AND PUMP.

Report.—The combined engine and pump is well constructed, and adapted for use either as a steam pump or steam engine.

180. The Wm. Cramp & Sons Steam Engine Building Co., Philadelphia, Pa., U. S.

SINGLE AND COMPOUND MARINE ENGINES, WITH SURFACE CONDENSERS.

Report.—These exhibits are first-class in design and workmanship, and contain some excellent distinguishing features.

181. The J. C. Hoadley Co., Lawrence, Mass., U. S.

PORTABLE STEAM ENGINES.

Report.—Commended for excellence of design and construction, both in boiler and engine, and for the successful application to engines of this class of the system of variable expansion, regulated by the governor, by which the highest economy of steam and uniformity of motion are attained, and this without departing from the simplicity of mechanism which is the feature of greatest value in the ordinary slide-valve.

182. Neafie & Levy, Philadelphia, Pa., U. S.

STEAM ENGINE.

Report.—Commended in that the vertical high-pressure steam engine is, in plan, material, and workmanship, of excellent character.

183. J. H. Mitchell, Philadelphia, Pa., U. S.

VERTICAL STEAM ENGINES.

Report.—Commended for fair design and construction.

184. Thos. Mills & Brother, Philadelphia, Pa., U. S.

VERTICAL ENGINE AND ICE-CREAM FREEZER COMBINED.

Report.—Commended for excellent design and adaptation to its use.

185. Copeland & Bacon, New York, N. Y., U. S.

REVERSIBLE WINDING ENGINE AND DIFFERENTIAL GEARED HOISTING ENGINES.

Report.—The winding and hoisting engines exhibited are of excellent construction and good workmanship. Their reversing and changing gear is of prompt and secure action and of high convenience for the engine driver.

186. Ward B. Snyder, New York, N. Y., U. S.

STEAM ENGINES AND BOILERS ONE TO THREE HORSE POWERS.

Report.—These are simple, substantial, and well made boilers and engines, and seem well adapted to supply the want of small powers.

187. R. O. Moorhouse & Co., Philadelphia, Pa., U. S.

STEAM ENGINE WITH GEAR FOR VARIABLE EXPANSION ADJUSTED BY THE GOVERNOR.

Report.—They exhibit a steam engine of excellent materials and workmanship, in which the speed is controlled by the degree of expansion, regulated by the Bilgram expansion gear, acted on by the governor.

188. Jacob Naylor, Philadelphia, Pa., U. S.

ENGINES, HORIZONTAL AND VERTICAL BOILER FEED-PUMP, AND COMBINED FEED-PUMP AND HEATER.

Report.—These exhibits are plain and mechanically correct in their design, and very well made.

189. Nelson W. Twiss, New Haven, Conn., U. S.

VERTICAL ENGINE AND YACHT ENGINE.

Report.—These are very small engines, simple in design, well made, and attractive in appearance.

190. Wisner & Strong, Pittston, Pa., U. S.

STEAM ENGINE WITH BALANCED VALVE.

Report.—This valve is the result of well-directed study, works well, and seems admirably adapted to its purpose, viz.: opening two passages for admission and for release of the steam.

191. I. P. Morris Co., Philadelphia, Pa., U. S.

BLAST ENGINE.

Report.—A fine exhibit of its class; first-rate workmanship and material; well designed for the purpose intended.

192. The Norwalk Iron Works Co., South Norwalk, Conn., U. S.

STEAM ENGINE.

Report.—The engine exhibited is very respectable in design and workmanship.

193. Richard Dudgeon, New York, N. Y., U. S.

ROTARY ENGINE.

Report.—In this engine the steam is admitted between the teeth of a pair of geared wheels as same are separating, and tends to force them apart. The design requires and has received very careful workmanship, and has proved successful after extended use.

194. Paulding, Kemble, & Co., West Point Foundry, N. Y., U. S.

MODEL OF DAVEY PUMPING ENGINE.

Report.—Commended for the very simple and ingenious valve gear, which acts as a safety apparatus and effects the distribution and cutting off of the steam, with a single slide-valve for each cylinder, and is adaptable for use with poppet valves.

195. Allison & Bannan, Port Carbon, Pa., U. S.

AIR COMPRESSING ENGINES.

Report.—Commended for good design and workmanship; plain and efficient.

196. Shapley & Wells, Binghamton, N. Y., U. S.

STEAM ENGINES AND BOILERS.

Report.—The engines exhibited are of very carefully studied form and construction, good design of the details, and very good workmanship. The arrangement by which the tubes in small vertical boilers are made accessible for cleaning and renewal is especially deserving of commendation.

197. Union Rock Drill Co., New York, N. Y., U. S.

AIR COMPRESSING ENGINE.

Report.—A good strong and plain engine, well designed for the work intended.

198. Hampson, Whitehill, & Co., New York, N. Y., U. S.

STEAM ENGINE.

Report.—A very well executed steam engine, with automatically regulated cut-off; the mechanism for the latter is of the greatest simplicity; the design of the engine very satisfactory.

199. Ames Iron Works, Oswego, N. Y., U. S.

PORTABLE STEAM ENGINES.

Report.—Commended for respectable design and workmanship.

200. T. F. Rowland, Greenpoint, N. Y., U. S.

PILLAR BEAM ENGINE.

Report.—This engine is substantial in design and construction.

201. Williamson Brothers, Philadelphia, Pa., U. S.

HOISTING ENGINES WITH SPUR AND FRICTIONAL GEARING.

Report.—The spur and frictional-gear hoisting engines exhibited by Williamson Brothers are of the first class in plan, materials, and workmanship, and the combinations whereby the hoisting drums are operated from same boiler, and all the incidents of hoisting, control, and delivery, are effected with great readiness and efficacy. The exhibit is of great interest for the objects in view.

202. Rider, Wooster, & Co., Walden, N. Y., U. S.

COMPRESSION ENGINES, OPERATING WITHOUT VALVES, USING COMPRESSED AND HEATED AIR.

Report.—The compressed air engines exhibited resolve very well the problem of putting in practice the principle of the so-called closed caloric engine. They run smoothly, and have no parts exposed to unusual wear.

203. Wm. D. Andrews & Brother, New York, N. Y., U. S.

BOILER.

Report.—Commended for efficiency, generating a large amount of steam within a small space.

204. Abraham Huffer, Hagerstown, Md., U. S.

AUTOMATIC STEAM VACUUM PUMP.

Report.—Commended for ingenuity in construction of automatic valve, facility in application, and economy when used with exhaust steam.

205. Niagara Steam Pump Works, Brooklyn, N. Y., U. S.

DIRECT-ACTING STEAM PUMPS.

Report.—Commended for superiority in accessibility of pump valves; excellent design of crank pump, adaptable for use as a steam engine; compactness in construction of mining pumps.

206. Nye, Gourlay, & Co., Chicago, Ill., U. S.

STEAM VACUUM PUMP.

Report.—The pump is of simple and cheap construction. The absence of piston makes it well adapted for moving fluids charged with gritty substances. It is considered, however, in the absence of an actual test, that the pump is adapted for general use only in localities where fuel is cheap or the duty of a temporary character.

207. Aquometer Steam Pump Co., Philadelphia, Pa., U. S.

STEAM PUMP.

Report.—The pump is tastefully designed, and of simple and cheap construction. The absence of piston makes it well adapted for moving fluids charged with gritty substances. It is considered, however, in the absence of an actual test, that the pump is adapted for general use only in locations where fuel is cheap or the duty is of a temporary character.

208. S. D. Hubbard & Co., Pittsburg, Pa., U. S.

STEAM PUMP.

Report.—The exhibit is a tastily-designed and well-constructed example of crank feed pumps.

209. Frederick Spiess, New York, N. Y., U. S.

STEAM PUMP (BEHRENS').

Report.—The valve motion is very ingenious, and, judging from the first pump constructed on this system, bids fair to operate with certainty and efficiency.

210. Exeter Machine Works, Boston, Mass., U. S.

SECTIONAL INDEPENDENT EXPANSION AND CONTRACTION STEAM BOILER.

Report.—The boiler exhibited is of the class of the so-called sectional boilers; it is composed of castings offering great resistance; it gives free circulation to the heated water and the steam, and is easily accessible.

211. Valley Machine Co., Easthampton, Mass., U. S.**BUCKET PLUNGER STEAM PUMPS.**

Report.—Commended for simplicity, compactness, good design and workmanship.

212. Abendroth & Root Manufacturing Co., New York, N. Y., U. S.**WROUGHT-IRON SECTIONAL SAFETY BOILER.**

Report.—These boilers are entirely accessible, the tubes are readily removed; it gives steam free from water, and has a good circulation.

213. Baird & Huston, Philadelphia, Pa., U. S.**HORIZONTAL TUBULAR BOILER.**

Report.—The materials and workmanship are of the first class.

214. Hartford Steam Boiler Inspection and Insurance Co., Hartford, Conn., U. S.**SCALE AND DEFECTIVE IRON FROM STEAM BOILERS.**

Report.—The work done by this company is constructed on sound principles, and is of the highest importance to the community. Their system of boiler inspection affords almost an absolute security against explosions, as has been proved in the long experience of English companies, after which it has been modeled; and it is of real consequence that systems of the same general character should come into general use.

215. Hubbard & Aller, Brooklyn, N. Y., U. S.**STEAM AND AIR PUMPS.**

Report.—The valves of water-end of the steam pump are very accessible. The regulating apparatus and pump valves of duplex air pump are commendable.

216. Wm. E. Kelly, New Brunswick, N. J., U. S.**STEAM PUMP.**

Report.—The arrangement of pump valves gives direct water passages with small clearance, and the general design of the whole pump is neat and simple.

217. Wm. D. Hooker, Dedham, Mass., U. S.**DIRECT-ACTING STEAM PUMPS.**

Report.—The pump is compact and efficient, and the steam-cushion for main piston insures safety and smooth working.

218. Conde & Co., Philadelphia, Pa., U. S.**STEAM PUMPING ENGINE.**

Report.—Commended for ingenuity in design of steam and water valves.

219. Harrison Boiler Works, Philadelphia, Pa., U. S.**SECTIONAL SAFETY STEAM BOILER.**

Report.—Commended for the following reasons, viz.: that in the Harrison boiler great pressures of steam can be carried with great safety; that the great excess of strength in proportion to strains renders explosion in a high degree improbable; that the small amount of water set free, when any parts in combination give way, renders disastrous explosions

also in a high degree improbable. Of the economy of the boiler, of its character in reference to scale, and other incidents of water and use, the Board of Judges have no practical knowledge on which to base an expression of judgment.

220. John McConn, Philadelphia, Pa., U. S.

HOT-WATER BOILER AND STEAM RADIATOR FOR HEATING PURPOSES.

Report.—Commended for good design and efficiency.

221. George W. Harrold, Rochester, N. Y., U. S.

AUTOMATIC STEAM TRAP.

Report.—This is an apparatus designed to complete the circulation between a boiler and radiators, by returning the water formed by the condensation of the steam back to the boiler; and this it appears to do in a reliable manner.

222. Erie City Iron Works, Erie, Pa., U. S.

HORIZONTAL TUBULAR BOILERS AND ENGINES.

Report.—The engines and boilers exhibited are, in material, proportions, and workmanship, of a character likely to furnish good and durable engines. The engines are on well-established plans, except that in the large stationary engine provision is made for using steam expansively by valve gear, adjustable by hand, when the engine is in motion.

223. John T. Shuster, Philadelphia, Pa., U. S.

FELTING FOR BOILERS AND STEAM PIPES.

Report.—This is shown to be an excellent non-conducting covering.

224. A. H. Woodruff, Lansing, Iowa, U. S.

GEAR FOR LOCOMOTIVE AND PROPELLER ENGINES, FOR REVERSING AND EXPANSION.

Report.—This is an original and ingenious construction, and appears to work extremely

225. Lowe & Watson, Bridgeport, Conn., U. S.

STEAM BOILER.

Report.—This is a tubular boiler, well made, and so constructed and set that the flame or heated gases, after being deflected by the side walls, enter a chamber above the furnace, where they have their direction again changed before entering the tubes; an arrangement which works very well.

226. Alonzo L. Jones, Philadelphia, Pa., U. S.

STEAM TRAPS.

Report.—Commended for simplicity and efficiency.

227. The Norwalk Iron Works Co., South Norwalk, Conn., U. S.

DIRECT-ACTING NON-EXPANSIVE STEAM PUMP.

Report.—Commended for simplicity and good workmanship.

228. Adam Carr, New York, N. Y., U. S.

STEAM PUMP, STEAM RADIATOR, HOISTING ENGINES, AND CONDENSERS.

Report.—Commended for ingenuity in design of compound direct-acting steam pump with condenser. The radiator is a good example of its class.

229. Rogers & Black, Philadelphia, Pa., U. S.

BOILER.

Report.—This boiler has a strong circulation through the external pipes, and seems to avoid in a large degree the defects common to vertical boilers.

230. G. F. Blake Manufacturing Co., Boston, Mass., U. S.

BLAKE'S PATENT STEAM PUMPS.

Report.—Commended for the large and attractive display of steam pumps, uniformly excellent in design and workmanship, which, in various forms adapted to the work to be done, have proved their reliability and efficiency by extended use.

231. Alfred Gomersall, Philadelphia, Pa., U. S.

ENGINES AND PUMPS.

Report.—An exhibit of pumps of simple and strong construction.

232. Lovegrove & Co., Philadelphia, Pa., U. S.

VERTICAL TUBULAR BOILERS.

Report.—Commended for respectable construction.

233. I. A. Grosvenor, Jersey City, N. J., U. S.

PULSOMETER STEAM PUMP.

Report.—This pump, operated by pressure of steam on a surface of water, is tastefully designed and of simple and cheap construction. The absence of pistons makes it well adapted for moving fluids charged with gritty substances. It is considered, however, in the absence of an actual test, that the pump is adapted for general use only in locations where fuel is cheap or the duty of a temporary character.

234. Henry Vogt & Brothers, Brooklyn, E. D., N. Y., U. S.

BOILER.

Report.—Commended in that the horizontal tubular boiler, with furnace below and return through tubes, is, in plan, material, and workmanship, of the first class.

235. Edward Purvis, New York, N. Y., U. S.

AUTOMATIC STEAM VALVE.

Report.—Commended for ingenuity and simplicity.

236. Hilles & Jones, Wilmington, Del., U. S.

DIRECT-ACTING STEAM PUMP.

Report.—A very simple and ingenious compound direct-acting steam pump.

237. J. & George Firmenich, Buffalo, N. Y., U. S.

BOILER.

Report.—This boiler is strong, has good circulation, and is accessible for repairs.

238. C. R. Patterson, Pittston, Pa., U. S.

SUCTION AND BLAST FAN.

Report.—Commended as a fair specimen of its class, and especially well adapted for suction fan.

239. Craig & Brevoort, New York, N. Y., U. S.

CONDENSER FOR STEAM PUMPS.

Report.—The exhibitors have developed and successfully introduced a condenser which can be applied in the main suction pipe of a steam pump in such manner that no additional air pump is needed; the apparatus being also adaptable for use with a special air pump.

240. L. J. Knowles, New York, N. Y., U. S.

STEAM PUMPS.

Report.—The designs and workmanship are very superior. The pumps in various forms, adapted to the work to be done, and exemplified by the excellent display in the Exhibition, have proved their reliability and efficiency by extended use.

241. John A. Reed, New York, N. Y., U. S.

TAPERING CORRUGATED SECTIONAL BOILERS.

Report.—Commended in that the arrangement and combination of taper corrugated pipes of the Reed sectional boiler provides favorably for the creation of heat and its reception by the pipes, and that in the material and proportion of parts large provision is made for strength. The combination provides a safe boiler, at a low cost, with good results in operation.

242. Geo. S. Follensbee, Lewistown, Me., U. S.

DOUBLE PROPELLER PUMP.

Report.—The double series of propellers is considered to be an improvement in propeller pumps. The pump operates well, has direct passages and no valves; but, the system being comparatively new, no opinion can be formed without trial as to its efficiency compared with other kinds of pumps.

243. Babcock & Wilcox, New York, N. Y., U. S.

SECTIONAL SAFETY STEAM BOILER.

Report.—The steam boiler exhibited, being of the class of the so-called sectional boiler, is in all parts very well accessible, allowing well the repair of a tube when damaged. It gives the heated water a free circulation, and to the steam generated in the tubes clear passage to the steam room. It also allows free expansion to the parts exposed to the greatest heat.

244. S. S. Vail, Keokuk, Iowa, U. S.

REVERSIBLE STEAM BOILER.

Report.—The exhibited boiler is of novel construction, which allows the boiler to be cleaned and kept in order more easily than the finer ones; the construction, although only applicable for smaller powers, offers therefor advantages.

245. Stillman B. Allen, Boston, Mass., U. S.

GOVERNOR FOR STEAM ENGINES.

Report.—This is an excellent form of governor of the class in which a fluid is employed. The revolution of a fan wheel imparts corresponding motion to the fluid in which it revolves. This impinges against ribs cast in the chamber, and so causes the chamber to revolve. The revolution of the chamber is resisted by a weight suspended from a wheel made slightly eccentric, so that minute changes of velocity of the fluid cause this wheel, and also an arm and valve, to take different positions. The forces in counteraction may be as strong as desired.

246. Wm. Sellers & Co., Philadelphia, Pa., U. S.

INJECTOR.

Report.—Commended in that they exhibit an injector that is self-regulating, is simple in plan, readily operated, and is in material and workmanship of the highest order.

247. Wm. Sellers & Co., Philadelphia, Pa., U. S.

SHAFTING, COUPLINGS, AND HANGERS.

Report.—Well-established excellence in workmanship and design.

248. Lonergan & McBride, Philadelphia, Pa., U. S.

OIL CUPS AND LUBRICATORS.

Report.—Commended for having exhibited lubricators with adjustable outlet, being well shaped, and showing very good workmanship.

249. Thomas Foulds, Jr., Trevorton, Pa., U. S.

CONDENSER.

Report.—The exhibit is a very simple and efficient condenser for steam pumps.

250. Wm. Burnett, Baltimore, Md., U. S.

LUBRICATING APPARATUS FOR STEAM ENGINES.

Report.—A very reliable and useful instrument, well adapted for the purpose intended.

251. C. M. O'Hara & Co., Boston, Mass., U. S.

FELTING FOR COVERING STEAM BOILERS AND PIPES.

Report.—This is a preparation of value for the purpose intended.

252. Union Brass Works, Wm. Powell & Co., Cincinnati, Ohio, U. S.

LUBRICATORS AND VALVES.

Report.—The lubricators exhibited are provided with novel and useful arrangements; also the valves are improved, both showing elegant design as well as excellent workmanship.

253. John W. Hanmore, Newburgh, N. Y., U. S.

COMBINATION FELTING FOR COVERING STEAM BOILERS AND PIPES.

Report.—This is believed to be a good method of protecting against loss of heat by radiation.

254. Woodruff & Beaumont, Kankakee City, Ill., U. S.

STOP VALVE.

Report.—Commended for good workmanship and easy manipulation.

255. Herman V. Hetzel, Philadelphia, Pa., U. S.

SPEED INDICATOR.

Report.—Commended for the simple and excellent adaptation of a conical pendulum, with spring resistance and index, to accomplish the purposes intended.

256. Thomas Ross, Rutland, Vt., U. S.

STEAM CRANE.

Report.—The crane of ten tons' capacity is cheaply but substantially constructed, and devices for raising, lowering, traversing, and turning are provided and arranged in a compact and convenient manner.

257. S. S. Jamison, Jr., Saltsburg, Pa., U. S.

STEAM WATER INJECTOR.

Report.—Commended for simplicity and good workmanship.

258. John F. Taylor, Charleston, S. C., U. S.

STEAM AND HYDRAULIC COTTON PRESS.

Report.—Commended for great efficiency, with economical use of fuel, and adaptability to the purpose intended.

259. E. H. Ashcroft, Boston, Mass., U. S.

STEAM AND VACUUM GAUGES AND SAFETY VALVES.

Report.—Commended for excellent manufacture of gauges on the Bourdon system, fidelity of construction affording a guaranty of correct action maintained through a long period of use.

260. Malleable Iron Fittings Co., Branford, Conn., U. S.

STEAM AND GAS PIPE AND CASTINGS.

Report.—It presents an extensive assortment of malleable cast-iron fittings for steam and gas pipe, which have for some years held a position in the market as first-class articles.

261. T. R. Pickering, Portland, Conn., U. S.

GOVERNORS FOR STEAM ENGINES.

Report.—Commended for excellent construction and satisfactory action.

262. Utica Steam Gauge Co., Utica, N. Y., U. S.

GAUGES, COUNTERS, AND GAUGE TESTERS.

Report.—The steam gauges exhibited are of very durable and reliable construction, and easily corrected if injured. The testing pump exhibited is of simple and reliable construction, and a very useful instrument for boiler and manometer testing purposes.

263. Marmont B. Edson, New York, N. Y., U. S.

EDSON'S TIME AND PRESSURE RECORDING GAUGES.

Report.—The time and pressure recording gauges shown by him have been very much improved since their first introduction, and now appear to be efficient and reliable instruments, while the importance of an instrument of this class, which can be depended upon, can hardly be estimated too highly.

264. R. J. Barr, Philadelphia, Pa., U. S.

STEAM TRAP.

Report.—The steam trap exhibited is of simple, uninterrupted operation, and great perfection of operating parts, well adapted to furnish a reliable instrument.

265. Charles T. Holloway, Baltimore, Md., U. S.

CHEMICAL FIRE ENGINE.

Report.—A simple and strong specimen of its class; of very good and solid workmanship.

266. Champion Fire Extinguisher Co., Louisville, Ky., U. S.

CHEMICAL ENGINES, HOOK AND LADDER TRUCKS.

Report.—A good exhibit of their class; strong and substantial.

267. Rumsey & Co., Seneca Falls, N. Y., U. S.

HAND FIRE ENGINES.

Report.—A good and highly-finished exhibit of hand fire engines.

268. B. S. Nichols & Co., Burlington, Vt., U. S.

VERTICAL STEAM FIRE ENGINE.

Report.—Commended as simple, compact, and strong, and of good workmanship.

269. Protective Fire Apparatus Co., New York, N. Y., U. S.

APPARATUS FOR EXTINGUISHING FIRES.

Report.—This is a very complete system, and has been shown by experiment to be completely effective for the extinguishment of fire in closed chambers, as warehouses and the holds of vessels, by carbonic acid gas, in oil tanks by injecting carbonic acid gas into the body of the oil, and in open situations by attacking the fire with water highly charged with carbonic acid gas or containing an excess of alkali.

270. A. F. Spawn & Co., New York, N. Y., U. S.

CHEMICAL FIRE ENGINE, HOOK AND LADDER TRUCKS, AND FIREMEN'S SUPPLIES.

Report.—A good exhibit for throwing gas and water by the means designated.

271. Clapp & Jones Manufacturing Co., Hudson, N. Y., U. S.

PISTON STEAM FIRE ENGINES.

Report.—Good design and workmanship; highly finished.**272. La France Manufacturing Co., Elmira, N. Y., U. S.**

ROTARY STEAM FIRE ENGINE.

Report.—Commended as strong, compact, and of good workmanship.**273. The Gould's Manufacturing Co., Seneca Falls, N. Y., U. S.**

HAND FIRE ENGINE.

Report.—Commended as a splendid exhibit of its class, strong and compact.**274. L. Button & Son, Waterford, N. Y., U. S.**

STEAM FIRE ENGINE.

Report.—Commended as simple, strong, reliable, and a good machine of its class.**275. R. D. Wood & Co., Philadelphia, Pa., U. S.**

FIRE HYDRANTS, CAST-IRON PIPES, AND VALVES.

Report.—Commended for variety and good substantial workmanship. The valves are of simple construction and easily manipulated.**276. Wm. K. Platt & Co., Philadelphia, Pa., U. S.**

FIRE EXTINGUISHERS.

Report.—A good exhibit of its class; very portable.**277. John Woodville, Washington, Ind., U. S.**

GARDEN ENGINE AND FIRE EXTINGUISHER.

Report.—The garden engine and fire extinguisher has a pump of very simple construction, operating with little friction, and well calculated for the purpose intended.**278. Babcock Manufacturing Co., New York, N. Y., U. S.**

CHEMICAL ENGINES WITH HOOK, LADDER, AND HOSE ATTACHMENTS.

Report.—Chemical fire engines and extinguishers; a good exhibit of their class. The hook and ladder truck deserves special mention for the facility of handling the ladders.**279. George B. Brayton, Philadelphia, Pa., U. S.**

HYDRO-CARBON ENGINE.

Report.—This engine presents a new system for generating power, of great interest and promise, and which is so far developed as to have attained a very satisfactory degree of practical success.**280. Thomas C. Basshor & Co., Baltimore, Md., U. S.**

AUTOMATIC RELIEF VALVE FOR STEAM FIRE ENGINE.

Report.—Commended as a meritorious invention; certain in action.

281. Babson & Dwight, New York, N. Y., U. S.

SELF-REGULATING FIRE ESCAPE.

Report.—Commended as a simple and reliable apparatus.

282. James Flower & Brothers, Detroit, Mich., U. S.

STOP VALVE AND FIRE HYDRANT.

Report.—Commended for good workmanship, and as well adapted for the purpose intended.

283. R. T. H. Stileman, Philadelphia, Pa., U. S.

WATER GATES AND FIRE HYDRANTS.

Report.—Commended for good substantial workmanship and material.

284. C. Schanz, Philadelphia, Pa., U. S.

HOOK AND LADDER TRUCK.

Report.—A good exhibit of its class.

285. Blake Hose Co., Boston, Mass., U. S.

FIRE HOSE.

Report.—Commended for a good exhibit of canvas hose.

286. E. A. Street, New York, N. Y., U. S.

PORTABLE FIRE PUMP.

Report.—Commended for an ingenious idea of arrangement for transportation.

287. Louis Falk, Morrisania, N. Y., U. S.

PORTABLE FIRE ESCAPE.

Report.—Commended as very portable and simple apparatus, well designed for the purpose intended.

288. John E. Lindlaw, New York, N. Y., U. S.

FIRE ESCAPE.

Report.—The plan is original in some respects, and seems capable of some degree of useful application.

289. John Birkinbine, Philadelphia, Pa., U. S.

TREBLE FIRE HYDRANT.

Report.—Commended for good device, material, and workmanship.

290. Henry P. M. Birkinbine, Philadelphia, Pa., U. S.

FIRE PROTECTION APPARATUS.

Report.—Commended as very ingenious and well adapted to effect the purpose intended.

291. Samuel Y. Greer, Philadelphia, Pa., U. S.

HOSE CARRIAGE AND LEATHER FIRE HOSE.

Report.—Commended for good workmanship and strength; the hose carriage for highly-finished workmanship.

292. Mrs. Scott Uda, New York, N. Y., U. S.

AERIAL LADDER.

Report.—A splendid exhibit of its class; compact, strong, easy of manipulation, speedy in action.

293. Wannalanset Manufacturing Co., Boston, Mass., U. S.

LINEN FIRE HOSE AND HOSE COUPLINGS.

Report.—Commended for good workmanship, lightness, and strength.

294. Thomas H. Peto, Philadelphia, Pa., U. S.

HOOK AND LADDER TRUCK AND HOSE CARRIAGES.

Report.—A fair exhibit for the purposes claimed.

295. Albright & Stroh, Mauch Chunk, Pa., U. S.

FIRE PLUGS.

Report.—Commended as well adapted for the purpose intended; good workmanship.

296. W. H. Wilson, New York, N. Y., U. S.

FIREMEN'S HATS AND BELTS.

Report.—A good and strong specimen of its class.

297. Joseph Sewall Smith, Bangor, Me., U. S.

THE BANGOR SAFETY EXTENSION FIRE LADDER.

Report.—Commended for its easy manipulation and lightness.

298. Eureka Fire Hose Co., New York, N. Y., U. S.

SEAMLESS FIRE HOSE.

Report.—Commended as good, strong specimens of canvas hose.

299. Ryder Reciprocal Grate Association, Taunton, Mass., U. S.

RECIPROCAL GRATES.

Report.—Commended for having exhibited grates of practical and durable construction, provided with a well-acting mechanism to move the grate bars partially for the purpose of removing the ashes and cleaning the fire.

300. Joseph Woodruff, Rahway, N. J., U. S.

BALANCED STEAM-DAMPER REGULATOR.

Report.—This is an ingenious and effective regulator, possessing the sensibility and range of action of the Clark regulator, with the durability which was wanting in that instrument.

301. **W. Barnet Le Van, Philadelphia, Pa., U. S.**

DAMPER REGULATOR AND GRATE BARS.

Report.—Commended in that the damper regulator and grate bars are good and well-made instruments for their respective uses.

302. **Charles Toope, New York, N. Y., U. S.**

GRATE BARS.

Report.—In arrangement of bearing-surface and provision for shaking, is furnished an efficient instrument.

303. **J. B. Hoyt, New York, N. Y., U. S.**

FURNACE FOR THE COMBUSTION OF BITUMINOUS COAL.

Report.—The furnace is completely effective in consuming the smoke from bituminous coal.

304. **W. W. Tupper & Co., New York, N. Y., U. S.**

GRATES FOR STEAM-BOILER FURNACES.

Report.—Commended in that by the form, dimensions, and combination of the grate bars exhibited, there is obtained an area of air-space large in proportion to area of grate surface, on a supporting structure of form and dimensions providing durability of grate bars.

305. **Samuel S. Bent, New York, N. Y., U. S.**

SHAKING GRATE BARS FOR STEAM BOILERS.

Report.—This is an excellent arrangement of shaking grate bars.

306. **L. B. Tupper, New York, N. Y., U. S.**

FURNACE GRATE BARS.

Report.—Having exhibited grate bars of appropriate shapes, all of good quality, scarcely changed by heat, and being easily cleaned.

307. **Lalance & Grosjean Manufacturing Co., New York, N. Y., U. S.**

SEAMLESS SODA WATER FOUNTAINS AND GENERATORS.

Report.—Commended for first-class work of great strength. The glass fountains commended for their cleanliness.

308. **Charles Lippincott & Co., Philadelphia, Pa., U. S.**

APPARATUS FOR MANUFACTURING AND DISPENSING SODA WATER.

Report.—A splendid exhibit of its class; well designed; good workmanship.

309. **James W. Tufts, Boston, Mass., U. S.**

SODA WATER APPARATUS, GENERATORS, TUMBLER WASHERS.

Report.—Commended for elegant designs, good workmanship and materials; meritorious improvements of surface cooler and dispensing faucets.

310. **James W. Tufts, Boston, Mass., U. S.**

AUTOMATIC FOUNTAINS.

Report.—A splendid exhibit of its class; novel and beautiful.

311. John Matthews, New York, N. Y., U. S.

APPARATUS FOR MAKING, BOTTLING, AND DISPENSING SODA WATER.

Report.—An excellent exhibit of its class; very elegant designs, and best workmanship.**312. Michael Hey, Philadelphia, Pa., U. S.**

BEER PUMP, PATENT COOLERS, AND HYDRAULIC AIR MACHINE.

Report.—Commended for good workmanship and elegant design.**313. A. D. Puffer, Boston, Mass., U. S.**

BEER, SODA AND MINERAL WATER APPARATUS.

Report.—Commended for elegant workmanship and design, with modifications well adapted for the purpose intended.**314. Poole & Hunt, Baltimore, Md., U. S.**

PULLEYS AND FEED WATER HEATERS.

Report.—Commended for excellent design and workmanship; superior pulleys.**315. George V. Cresson, Philadelphia, Pa., U. S.**

PULLEYS, HANGERS, COUPLINGS, AND WALL BOXES.

Report.—Commended for excellent workmanship.**316. A. B. Cook & Co., Erie, Pa., U. S.**

ADJUSTABLE DEAD PULLEYS.

Report.—Commended for excellence of workmanship and arrangement of parts.**317. Jones & Laughlins, Pittsburg, Pa., U. S.**

SHAFTING, HANGERS, AND PULLEYS.

Report.—Commended for excellence of workmanship in all the articles exhibited, and especially in the round shafting, and other forms of sections of wrought iron, produced by cold rolling.**318. Pusey, Jones, & Co., Wilmington, Del., U. S.**

EXPANDING PULLEYS AND TREMPER CUT-OFFS FOR STEAM ENGINES.

Report.—The expanding pulleys are of simple and durable construction, and very useful in many special locations. The Tremper governor cut-off is remarkably simple, and may be very readily and cheaply applied to secure a fair measure of economy.**319. A. & F. Brown, New York, N. Y., U. S.**

ENGINE, PULLEYS, AND HANGERS.

Report.—Commended in that the engine is constructed on a well-established plan, without expansion gear, and is in materials and workmanship of the first class.

Excellence of design and workmanship of the hangers and pulleys.

320. Pancoast & Maule, Philadelphia, Pa., U. S.

STEAM AND HOT WATER HEATING APPARATUS AND RADIATORS.

Report.—The heating apparatus exhibited is of very good construction, and offers great security, as well as high heating power.

321. Henry Q. Hawley, Albany, N. Y., U. S.

GAS HEATING AND COOKING FURNACES.

Report.—Commended for efficiency and facility of application.**322. Armstrong Heater Manufacturing Co., Toledo, Ohio, U. S.**

IMPROVED HEATER, LIME EXTRACTOR, CONDENSER, ADJUSTABLE FEED PUMP FOR STEAM BOILERS.

Report.—This is what is termed an open heater, or one in which the feed water to be heated and purified is brought into contact with the steam, and is a well-designed heater of this class, and thoroughly effective.**323. Chas. R. Ellis, New York, N. Y., U. S.**

HOT WATER APPARATUS FOR HEATING BUILDINGS.

Report.—The heater exhibited is of a very practical form, is easily accessible, and allows the water a free circulation. The workmanship is of high rate.**324. J. B. Davis, Hartford, Conn., U. S.**

FEED WATER HEATER AND PURIFIER.

Report.—This is a very excellent heater, of the class in which the steam does not come into contact with the feed water. It effectually frees the water from sediment, earthy matter, and lime, without imparting to it any grease from the cylinder.**325. Stilwell & Bierce Manufacturing Co., Dayton, Ohio, U. S.**

LIME-EXTRACTING HEATER AND FILTER.

Report.—Commended in that the lime-extracting heater is in plan simple, compact, and efficient; and that in the use of removable shelves the water is exposed favorably to the action of the exhaust steam; and that the system of filtering provided is well devised for the object in view.**326. F. D. Chase, Boston, Mass., U. S.**

VENTILATING DECK IRON.

Report.—The construction provides for ventilation by means of an air chamber surrounding the pipe, the inlets to which can be regulated by a register.**327. M. C. Isaacs & Co., Chicago, Ill., U. S.**

STEEL WIRE BRUSHES.

Report.—Commended for substantial manufacture and good material.**328. James L. Jackson, New York, N. Y., U. S.**

IMPROVEMENTS IN MAKING PATTERNS AND CASTINGS.

Report.—This exhibitor has successfully developed the art of making plaster patterns for ornamental and thin castings, by the use of accurately-constructed tools for producing positive relative motion of sweeps or cutters, in curves or right lines, whereby the moulding beds and patterns may be constructed with an accuracy as respects form and thickness, and with a rapidity and cheapness, unapproachable by the best artisans in wood.

A process is also illustrated for making strong and sound castings of varying thickness,

by casting in the mould near the thin portions compensating masses of metal, to preserve a substantially uniform temperature and prevent strains in cooling.

These exhibits are of the highest interest, and are believed to represent an important advance in the art.

329. John Charlton, Philadelphia, Pa., U. S.

INTERNAL CLAMP COUPLING FOR SHAFTING MAIN DRIVING PULLEY WITH INTERNAL CLAMP HUB.

Report.—Commended for the invention of a very simple and effective coupling and mode of fastening pulleys on shafts.

330. John P. Gruber, Jersey City, N. J., U. S.

LIQUID ELEVATOR AND FILTERING APPARATUS.

Report.—The application of atmospheric pressure to raise fluids and accelerate filtration has been developed in detail by the exhibitor to a very interesting, creditable, and useful extent.

331. W. H. King, Philadelphia, Pa., U. S.

SOAP PRESS.

Report.—The press is simple in construction and efficient in its operation.

332. Lathrop Anti-Frictionate Co., New York, N. Y., U. S.

COMPOSITION FOR BEARINGS.

Report.—The exhibit consists of a number of finely-finished journal boxes filled with a graphitic compound, which appears to operate well on journals located where it is difficult to apply oil.

333. H. F. Haurey, Newark, N. J., U. S.

FLUE AND TUBE BRUSHES.

Report.—These are excellent articles for the purposes intended, made of a very good quality of steel wire, well secured, making an effective and durable brush.

334. Boomer & Boschert Press Co., Syracuse, N. Y., U. S.

PRESS.

Report.—The press combines the non-retracting advantages of the screw with the progressive augmentation of pressure due to the toggle joint. The details have been carefully designed to promote rigidity, convenience of operation, simplicity, general adaptation, and efficiency.

335. L. J. Knowles & Brother, Worcester, Mass., U. S.

HAND AND POWER CLOTH PRESS.

Report.—This is a screw press of good design and construction. Means are provided to operate the screw by hand and the nut of same by power, the two methods of operation being independent and not interfering one with the other.

336. Stow & Burnham, Philadelphia, Pa., U. S.

FLEXIBLE SHAFT AND TOOLS AND MACHINES OPERATED THEREWITH.

Report.—Commended for the very ingenious, simple, convenient, and highly useful flexible shaft, with tools and machines adapted for use therewith.

337. Roland Rhett, Baltimore, Md., U. S.

SPRING MOTOR FOR SEWING MACHINES.

Report.—Commended for excellent design and construction and practical utility.

338. Asbestos Patent Fibre Co., Philadelphia, Pa., U. S.

PACKING.

Report.—Commended for having exhibited asbestos packing of great variety; also other applications of asbestos fabrics for machinery purposes; all of excellent workmanship and well-understood forms and composition.

339. L. Katzenstein & Co., New York, N. Y., U. S.

METALLIC PACKING FOR PISTON RODS AND VALVE STEMS.

Report.—It presents an excellent method of applying soft metal rings to the purpose of steam packing.

340. Josiah A. Osgood, Boston, Mass., U. S.

METALLIC SPRING PACKING.

Report.—Commended for excellent construction; well adapted to secure practical success.

341. Jackson Richards, Philadelphia, Pa., U. S.

PISTON PACKING.

Report.—Commended for the substitution of packing pieces in place of bolts and nuts as a means of expanding the rings through the medium of the ordinary springs.

342. William Ruoff, Philadelphia, Pa., U. S.

DOUBLE AND SINGLE GEARED JACK SCREWS.

Report.—The jacks are well constructed, being provided with wrought-iron cut gears, and are very powerful and efficient.

343. United States Metallic Spring Packing Co., Boston, Mass., U. S.

STEAM PRESSURE PACKING.

Report.—Commended for an arrangement well adapted to make a steam-tight fit, without binding on the piston rod.

344. E. Lyon, Cambridge, Mass., U. S.

HYDRAULIC JACKS.

Report.—The exhibits are good examples of their class.

345. Dienelt & Eisenhardt, Philadelphia, Pa., U. S.

HYDRAULIC JACKS.

Report.—A good example of hydraulic jacks.

346. Canfield Manufacturing Co., Philadelphia, Pa., U. S.

PACKING.

Report.—The piston rod packing in composition and combination is well fitted to furnish the tightness and elasticity required.

347. Miller's Falls Co., Miller's Falls, Mass., U. S.**JACK SCREWS.**

Report.—The exhibit contains some good examples of cheaply-constructed but serviceable screw jacks.

348. Wyss & Studer, Zurich, Switzerland.**HYDRAULIC ENGINE.**

Report.—The engine is well designed and constructed, and operates efficiently without jar.

349. Edward Brown, Philadelphia, Pa., U. S.**REVOLUTION INDICATOR.**

Report.—The revolution indicator is of new construction. It aims to fulfill a lack in the series of measuring instruments, and will render, even in its present state, and more after having been slightly improved, valuable services to mechanical industry.

350. Hydraulic and Drainage Co., Wm. Burdon, Brooklyn, N. Y., U. S.**STEAM PRESSURE AND VACUUM PUMPS.**

Report.—The steam pressure pump is of simple and cheap construction. The absence of piston makes it well adapted for moving liquids charged with gritty substances. It is considered, however, in the absence of an actual test, that the pump is adapted for general use only in locations where fuel is cheap or the duty is of temporary character. The vacuum pump is commended for ingenuity in construction of automatic valve gear, facility in application, and economy when used with exhaust steam.

351. Crane Brothers Manufacturing Co., Chicago, Ill., U. S.**ELEVATORS, PUMPS, VALVES, AND COCKS.**

Report.—Elevator. Commended for good design and workmanship, and carefully studied details to prevent accident.

A model of hydraulic elevator. Commended for the following reasons: economy in the use of water under pressure, three hydraulic cylinders being provided, of which one, two, or the three may be used at the same time, to suit the load.

The steam pumps are commended for efficiency, well-considered details, and good substantial workmanship.

The valves and cocks are all of good standard workmanship and of good material.

352. Matthewman & Johnson, New Haven, Conn., U. S.**DEODORIZING EXCAVATING APPARATUS.**

Report.—Pump and valves very well adapted for pumping fluids charged with solid matter.

353. Isaac Hyneman, Philadelphia, Pa., U. S.**ODORLESS EXCAVATOR.**

Report.—Commended for simplicity in construction.

354. Odorless Excavating and Manufacturing Co., Philadelphia, Pa., U. S.**ODORLESS EXCAVATING APPARATUS.**

Report.—Pump and valves well adapted for pumping fluids charged with solid matter.

355. Putnam Machine Co., Fitchburg, Mass., U. S.

STEAM ENGINE AND TURBINE WHEEL.

Report.—The engine exhibited is of very fine design, and has a valve gear of very compact and simple construction, operated by the governor; the workmanship of the whole being excellent and worthy of imitation. Turbine wheel commended for excellence of workmanship in full-sized wheel, and for good design of register gates, exemplified by model.

356. Holmes, Peyton, & Taylor, London, England.

AIR COMPRESSOR.

Report.—Commended for a good exhibit of a very compact air compressor.

357. Appleby Brothers, London, England.

STEAM CRANES.

Report.—The portable steam cranes exhibited are of a high order of merit; are of a capacity of three, five, and seven tons, raised and delivered in a radius of fourteen feet. The plans provide for travel by steam or hand power.

In plans, proportions, materials, and workmanship, the exhibit is first-class.

358. J. & H. Gwynne, Hammersmith Iron Works, London, England.

MODELS OF COMPOUND SURFACE CONDENSING ENGINES.

Report.—The pair of compound surface condensing engines with centrifugal pumps for raising large quantities of water, as presented in their well-made model, are in plan and combination of great simplicity and directness of action, and well designed for the work to be performed.

359. Gwynne & Co., London, England.

CENTRIFUGAL PUMPS AND ENGINES.

Report.—Commended for excellent design and workmanship, and well-considered details.

360. Thomas Haynes & Sons, London, England.

HYDRONETTE AND WATER BRINGER.

Report.—The exhibit is very simple and efficient, and well adapted for the purposes intended.

361. J. Pickering, Globe Works, Stockton-on-Tees, England.

PUMPS, PULLEYS, HOISTS, STEAM AND WATER CYLINDER.

Report.—The pump a good example of its class.

The pulleys simple and efficient.

362. T. H. P. Dennis & Co., Chelmsford, London, England.

PATENT FULL WAY HIGH PRESSURE VALVES.

Report.—Commended for good exhibit of valves; good material and workmanship.

363. Frank Pease, Manchester, England.

STEAM PUMP.

Report.—The pump is of substantial construction, and embodies a very valuable externally operated packing for the double-acting plunger.

364. Sanderson & Proctor, Huddersfield and London, England.

AUTOMATIC FIRE EXTINGUISHER AND ALARM.

Report.—Commended for meritorious invention.

365. Tangye Brothers, Cornwall Works, Birmingham, England.

HYDRAULIC LIFTING JACKS, SCREW LIFTING JACKS.

Report.—Commended as a good example of plain, screw traversing, and hydraulic jacks.

366. Adair & Co., Liverpool, England.

SHIP PUMP.

Report.—Commended for accessibility of valves, and adaptability for use on shipboard with ordinary labor.

367. Hiram Codd, London, England.

PATENT GLOBE STOPPERED SODA-WATER BOTTLE.

Report.—A good, meritorious invention.

368. Gwynne & Co., London, England.

GAS EXHAUSTER.

Report.—Commended as a reliable, compact machine, well adapted for the purpose intended; of excellent workmanship.

369. Edward Green & Son, Wakefield, England.

FUEL ECONOMIZER FOR HEATING THE FEED WATER FOR STEAM BOILERS.

Report.—They exhibit a fuel economizer to be used in connection with steam boilers. It consists in combination with a boiler of any kind, of an extensive series of vertical pipes, through which the feed water passes. The surfaces of the pipe are kept free from soot by the continuous action of scrapers fitted to the surface of the pipe, operated by its own engine. The arrangements by which the plans are carried into operation are of the best character.

370. Dillwyn Smith, Liverpool, England.

AUTOMATIC STOKER.

Report.—This is a most efficient attachment to a boiler furnace, feeding fine or small-sized coal regularly, and distributing it evenly, capable of any required adjustment, enabling the fires to be kept in uniform condition, and avoiding occasion for opening the doors.

371. Lawrence & Co., London, England.

REFRIGERATORS.

Report.—Commended for simplicity and efficiency, offering a very large cooling surface, and requiring but small space.

372. Siebe & Gorman, London, England.

DIVING APPARATUS.

Report.—Commended for very excellent workmanship; details very carefully designed.

373. Joseph E. Holmes, London, England.

FOUR-CYLINDER ENGINE.

Report.—The four-cylinder combination presents a balanced development of power of great uniformity, through a combination of parts that provide for satisfactory operation.

374. Davey, Paxman, & Co., Colchester, Essex, England.

PORTABLE STEAM ENGINE AND VERTICAL BOILER.

Report.—Commended for having exhibited a portable and semi-portable engine of very substantial and durable character and in a high degree fit for the purpose intended.

375. W. & J. Galloway & Sons, Knott Mill Iron Works, Manchester, England.

STEEL BOILERS FOR USE IN BRITISH SECTION.

Report.—Commended for having exhibited a very good steam boiler of great practical usefulness provided with the tubes called after the exhibitor; and for having contributed by the introduction of these tubes to the practical application of steam power.

376. James J. Hicks, London, England.

WATER GAUGES.

Report.—Commended in that the several water gauges are in plan and workmanship of the first class, and give the water gauge an unusual value as an instrument.

377. John Moncrieff, North British Glass Works, Perth, Scotland.

GAUGE GLASSES.

Report.—The glasses for water gauges exhibited sustain the high character of the glasses furnished by the exhibitor, having the essential quality of material required for the uses to which they are to be put.

378. Mirlees, Tait, & Watson, Glasgow, Scotland.

SUGAR MILL AND STEAM ENGINES AND CENTRIFUGAL MACHINES.

Report.—The engine by which the sugar mill of large size (rolls thirty-six inch diameter, seven feet long) is driven is a six-column engine using Corliss valve gear, and in the engine working the air pump a long piston having reciprocating angular motion performs the functions of valves. Both are, in plan, proportions, materials, and workmanship, of the first class, and the whole exhibit is an impressive presentation of the power of steam applied to the extraction of the juice of the sugar-cane.

379. William Wright, Vulcan Foundry, Coatbridge, Scotland.

HOT WATER BOILERS.

Report.—Commended for having exhibited a very practically arranged water boiler designed for heating dwellings, being simple in construction, offering a relatively large heating surface adapted to small rooms.

380. A. Le Grande, Melbourne, Victoria, Australia.

PATENT ABYSSINIAN TUBE WELLS, AND PUMPS, WITH BORING APPARATUS.

Report.—Commended for the interesting exhibit of well-designed tools, tubes, and pumps, intended for the rapid construction and immediate and efficient use of tube wells.

381. T. D. Postle, Sydney, New South Wales, Australia.

PORTABLE ICE MAKER AND WATER COOLER.

Report.—Commended as a simple and useful machine for hot climates.

382. A. A. Murphy, Montreal, Canada.

PNEUMATIC FIRE EXTINGUISHER.

Report.—Simple, cheap, and effective apparatus, easily managed.

383. Wm. Kennedy & Sons, Owen Sound, Ontario, Canada.

WATER-WHEEL.

Report.—Commended for good workmanship.

384. Barber & Harris, Meaford, Ontario, Canada.

WATER-WHEEL.

Report.—Commended for good workmanship.

385. John Ritchie & Son, Toronto, Ontario, Canada.

COCKS, VALVES, AND LUBRICATORS.

Report.—Commended for good workmanship.

386. Dixon, Smith, & Co., Toronto, Ontario, Canada.

LEATHER BELTING.

Report.—Commended for the excellent finish and good construction of the belting exhibited, which appears to have been made from hemlock-tanned leather.

387. Bowes & Son, Stratford, Ontario, Canada.

FORCE PUMPS.

Report.—Commended for ingenuity as to combination of the material used in the construction.

388. M. E. Dailey, Ottawa, Ontario, Canada.

TELESCOPE TRESTLE.

Report.—Commended for the facility with which the height of the trestles may be changed to adapt them to the location and work.

389. Small & Fisher, Woodstock, New Brunswick.

BARREL LIFTER.

Report.—This is a simple and efficient apparatus, and consists of a hoop hinged at opposite points, with intermediate handles.

390. S. Webster, St. Catharine's, Ontario, Canada.

OIL STORING TANK.

Report.—The exhibit furnishes an ingenious, safe, and convenient means of storing and drawing explosive oils.

391. Geo. Brush, Montreal, Canada.

STEAM ENGINE.

Report.—The hoisting steam engine on wheels is in plan, materials, and workmanship of good and substantial character.

392. James Morrison, Toronto, Ontario, Canada.

STEAM VACUUM AND HYDRAULIC GAUGES.

Report.—Having exhibited manometers of solid construction and good workmanship.

393. George Fleming & Sons, St. John, New Brunswick.

OSCILLATING ENGINE.

Report.—The exhibit presents an oscillating engine of good material and workmanship.

394. Robert Bustin, St. John, New Brunswick.

FIRE ESCAPE.

Report.—Commended as simple, useful, and reliable.

395. Oakville Manufacturing Co., Oakville, Ontario, Canada.

PUMPS.

Report.—The exhibits are good examples of their class.

396. H. W. Cox, Peterborough, Ontario, Canada.

ROTARY FORCE PUMPS.

Report.—Commended for good workmanship.

397. Robert Patrick, Galt, Ontario, Canada.

ROTARY PUMP.

Report.—Commended for good design.

398. John D. Ronald, Chatham, Ontario, Canada.

STEAM FIRE ENGINE.

Report.—Commended for durability, simplicity, good workmanship, and efficiency.

399. Wilson, Clark, & Co., Yarmouth, Nova Scotia.

SHIP PUMP.

Report.—Commended for accessibility of valves.

400. C. C. Jones, Fredericton, New Brunswick.

BARREL PUMP.

Report.—The exhibit shows an efficient combination of wood and iron in the construction of pumps.

401. F. W. Tuerk, Berlin, Ontario, Canada.

WORKING MODEL WATER-WHEEL.

Report.—Commended for economy in the use of water where small amount of power is required.

402. John Date, Montreal, Canada.

DIVING APPARATUS.

Report.—The work is substantial, and the details are well designed to secure efficiently the purposes intended.

403. C. Barns, Sackville, New Brunswick.

ROTARY PUMP.

Report.—Commended as a good specimen of its kind.

404. Waterous Engine Works Co., Bransford, Ontario, Canada.

STEAM ENGINE DRIVING A CIRCULAR SAW.

Report.—Commended for very simple and convenient construction of the engine, which drives directly the shaft of the circular saw, reliable workmanship, and fitness for the proper purpose intended.

405. Goldie & McCulloch, Galt, Ontario, Canada.

TURBINE WATER-WHEEL AND STEAM ENGINE.

Report.—Turbine water-wheel commended for excellent workmanship.

The steam engine exhibited is of a very substantial, solid character, and shows plain and careful workmanship.

406. The Thomson & Williams Manufacturing Co., Stratford, Ontario, Canada.

STATIONARY ENGINE.

Report.—The engine exhibited is on well-approved plan, and in material and workmanship of excellent character.

407. Geo. Fleming & Sons, St. John, New Brunswick.

OSCILLATING STEAM ENGINE.

Report.—The oscillating engine exhibited is on well-approved plans, and is of good material and workmanship.

408. Imperial Technological School, Moscow, Russia.

STEAM ENGINE, PARALLEL MOTION, AND GOVERNOR.

Report.—The engine and parts named are specimens of a high order in plan, materials, and workmanship; the parallel motion of great interest in its perfection of line, and governor in its uniformity of regulation. The combinations are useful in the arts, and to the student illustrate the adaptation of mechanical means to ends.

409. Cronstadt Steam Engine Works, Cronstadt, Russia.

STEAM ENGINE AND BOILER FOR A BARGE.

Report.—Commended in that the exhibit comprises a steam engine of which the peculiarity is that by a new combination of radius arms the head of the piston rod moves in the line of the cylinder; a governor differing from the governor of Watt in dimensions and forms of its parts, and in the use of a weight that can be increased, whereby a governor of great sensibility and uniformity is obtained; a drawing instrument by the use of which arcs of circles of large radii are truly drawn, and a parallel motion carrying a surface (as of a table) in the same plane; and that the engine and instruments are of great accuracy of construction.

410. Cronstadt Steam Engine Works, Cronstadt, Russia.

DRY DOCK, STEAM ENGINE, AND BOILER.

Report.—That the exhibit contains a model of the dry dock and appurtenances at Cronstadt, presenting clearly the character and arrangement of the dock; also the fire apparatus for the protection of the docks, and a yacht steam engine, with boiler and connections, the plan, materials, and workmanship of which are of the first class.

The exhibit, as a whole, is of a highly interesting character.

411. Lilpop, Rau, & Loewinstein, Warsaw, Russia.

PORTABLE STEAM ENGINE.

Report.—This engine is simple, substantial, and strongly made.

412. Michael Friedland, St. Petersburg, Russia.

PUMP, ROTARY SYSTEM.

Report.—The self-adjusting packing is meritorious, and the pump in other respects a well-made example of its class.

413. Adolphus Troetzer, Warsaw, Russia.

HAND FIRE ENGINE.

Report.—Commended as simple, compact, and of good workmanship.

414. Admiralty Ijora Works, near St. Petersburg, Russia.

DIVING APPARATUS.

Report.—Commended for valuable distinctive features, general simplicity of construction, and excellent workmanship.

415. Nicholas Iagn, St. Petersburg, Russia.

LABORATORY VACUUM PUMP.

Report.—This little instrument is an interesting example of apparatus for producing vacuum with an intermittently broken column of water, and should prove of great value in chemical investigations.

416. Admiralty Ijora Works, near St. Petersburg, Russia.

TRANSPORTABLE FIRE PUMP, AND DOWNTON'S SHIP PUMP.

Report.—A little transportable fire pump, commended for very good workmanship; and a Downton's ship pump, commended for very practical construction and excellent workmanship.

417. N. Wonlarlarsky, St. Petersburg, Russia.

PORTABLE TRAVELING CRANE.

Report.—The portable traveling crane "Groosokat" (transportable mechanism for the transshipment of burdens up to ten hundredweight) is commended for ingenuity in adaptation, simplicity of construction, and facility of application.

418. Pootilof Iron Works Co., St. Petersburg, Russia.

STEAM ENGINE.

Report.—The engine is of interest as being on the plan on which the piston, duly furnished with posts and passages and having angular motion at the same time that it has reciprocating motion, is the steam and exhaust valve of the engine. The workmanship and material of excellent character.

419. Gustavus Lessnér, St. Petersburg, Russia.

STEAM CYLINDER AND VALVES.

Report.—Commended in that the cylinder and valves are of the highest order in plan, material, and workmanship. As a specimen of metal, accurate execution, and high perfection of working parts, the exhibit is of great interest.

420. Bruno Hofmark, St. Petersburg, Russia.

WIRE DRIVING BELT (SPAKORSKY'S SYSTEM).

Report.—The exhibit is of great interest, and, so far as judgment can be formed without an extended test, bids fair to furnish a novel, cheap, and efficient means of transmitting power.

421. Temler & Schwede, Warsaw, Russia.

LEATHER BELTING.

Report.—Commended for the excellent finish and good construction of the belting exhibited, made from Russia tanned leather.

422. Mignon & Rouart, Paris, France.

NOISELESS GAS MOTORS.

Report.—The construction of the gas engine is of great simplicity. The engine can render good service in cases where economy of gas is not of the first importance.

423. De la Coudré, Asnières, France.

OIL CUPS AND FIRE-PROOF INSULATOR FOR STEAM PIPES.

Report.—Commended for having exhibited a complete series of good and substantial glass oil cups in different forms and varieties.

424. Defresne, Paris, France.

SELF-OILING BOX.

Report.—Commended for useful invention.

425. J. Chrétien, Paris, France.

AUTOMATIC APPARATUS FOR UNLOADING COAL.

Report.—Commended for ingenuity, simplicity, and efficiency.

426. Mégy, Echeverria, & Bazan, Paris, France.

ELEVATORS AND REGULATORS.

Report.—Commended for ingenuity, compactness, and great utility.

427. L. Neut & L. Dumont, Paris, France.

CENTRIFUGAL PUMPS.

Report.—Commended for simplicity, good workmanship, and great efficiency.

428. Bourdin & Co., Paris, France.

TREADLE MOTION FOR SEWING MACHINES.

Report.—Commended for the simple, ingenious, and efficient means for producing rotary from reciprocating motion without dead centres, adapted to sewing machines.

429. Garlandat, Paris, France.

REFRIGERATING APPARATUS.

Report.—A useful apparatus of very simple construction.

430. Chameroy & Co., Paris, France.

TAPS AND SHEET-IRON PIPES.

Report.—Taps commended for the ingenious arrangement for preventing the ram of water in ordinary taps.

The sheet-iron pipes are commended for their lightness and cheapness, and as a useful invention.

431. Edmond Rous, Paris, France.

PULLEYS AND OIL CUP COVERS.

Report.—The pulleys are provided with conveniently-operated, well-constructed catches, to hold the weight lifted at any desired elevation. The oil cup covers are provided with springs to hold them in position, and fit tightly conical openings in the cup so as thoroughly to exclude dust.

432. C. Dechamp, Lyons, France.

SAFETY BOILER APPARATUS.

Report.—A very well arranged apparatus for regulating the generating of steam in the steam boiler; for signaling the want of water and preventing the boiler from being overheated in the failure of water, and for giving escape to the water when exposed to damaging fire.

433. Hippolyte Fontaine, Paris, France.

STEAM ENGINE.

Report.—The small engine exhibited has a novelty in its safety apparatus, avoiding the useless consumption of gas in a way as simple as practical.

434. León Moreau, Brussels, Belgium.

FIRE ENGINE PUMPS.

Report.—Commended for ingenuity, efficiency, and good workmanship.

435. P. van den Kerchove, Ghent, Belgium.

CORLISS AND RIDER ENGINES.

Report.—The Corliss engine exhibited is of excellent workmanship and most careful design, showing besides, in shape and finish of the parts, the intelligent application of properly adapted automatic tools for the manufacture of the different pieces.

436. L. Dolne & Son, Verviers, Belgium.

BELTING.

Report.—The exhibit shows portions of belts of very good construction, made from thoroughly tanned leather.

437. Ant. Versé-Spelmans, Brichot, & Co., Brussels, Belgium.

BELTING.

Report.—The belts are well finished, and constructed in a superior manner of excellent leather; pliable and well-made hair belts are also shown, well adapted for use in wet locations.

438. Horstmans Brothers, Liège, Belgium.

BELTING.

Report.—Commended for the excellent finish of the portions of leather belting shown, and the various efficient modes of fastening the laps.

439. Artificial Leather Co., Copenhagen, Denmark.

BELTING.

Report.—The exhibit includes various articles made from a composition of leather scraps, rubber, etc. The belt exhibited, two and a half inches wide and sixteen one-hundredths inch thick, contained an insertion of canvas, and possessed a high degree of pliability. Its tensile strength was found by trial to be two thousand two hundred and fifty pounds.

440. Col. Rafael Cerero, Havana, Cuba.

HOISTS FOR SMALL WEIGHTS.

Report.—The drawings show simple and ingenious devices for efficiently accomplishing the purposes intended by the use of cheaper and lighter materials than have heretofore been employed. The appreciation of the necessities of the future shown by this officer, in applying his talents to produce economy in construction and operation, cannot be too highly commended.

441. Navy and Army Arsenal, Rio de Janeiro, Brazil.

MODELS OF MARINE ENGINES, SCREW PROPELLERS, HANGERS, AND SHAFTING.

Report.—The designs of the direct-acting marine engines are entitled to great credit for simplicity and accessibility. The mechanical work on the exhibits is plain but substantial, and shows creditable progress in the development of an industry comparatively new in that country.

442. F. C. Da Costa, Navy Yard, Rio de Janeiro, Brazil.

PUMPS AND HYDRAULIC RAMS.

Report.—Commended for good workmanship.

443. Zanini, Rome, Italy.

STEAM ENGINE.

Report.—The portable steam engine and boiler exhibited is in plan, materials, and workship of the first class, and well arranged and combined in all details.

444. Aron Hirsch & Son, Messingwerk, near Neustadt-Ew., Germany.

SEAMLESS COPPER AND BRASS TUBES.

Report.—Commended for good workmanship and material.**445. C. W. Julius Blancke & Co., Merseburg, Germany.**

MANOMETER, COUNTERS, AND OTHER MEASURING INSTRUMENTS.

Report.—The instruments exhibited are of solid character of construction, and good design and workmanship.**446. Buss Brothers, Magdeburg, Prussia, Germany.**

GOVERNORS, CALLED COSINE GOVERNORS.

Report.—The governor, exhibited in two samples, is of a new construction, and shows in the highest degree practically known the qualities of *pseudoastasia* and sensibility, being besides provided with arrangements for adjustment in reference to both the said qualities if wanted for different applications.**447. Emanuel Alleoud, Metz, Germany.**

JACK AND SIPHON PUMP.

Report.—The exhibit comprises a substantial ratchet jack, constructed entirely of wrought iron, and a very simple and efficient siphon pump.**448. Gas Motor Factory, Deutz, Germany.**

GAS MOTORS.

Report.—The gas engines exhibited are of a principle enabling the engine to work with a very high degree of economy of gas; the mechanism constituting their moving parts is distinguished by carefully fulfilling the conditions of prompt and durable action, and show very good workmanship; the engines are brought quite to perfection, and are well adapted to general service.**449. George Bodemer, Zschopau, Saxony, Germany.**

REGULATORS.

Report.—The governors exhibited are of a new system, properly adapted for the regulation of water-wheels and turbines of either large or small size, being nevertheless well applicable for steam engines. They act upon very small variations of speed with considerable energy, and are of very good workmanship.**450. Ernst Schultz, Aschaffenburg, Germany.**

ATMOSPHERIC APPARATUS.

Report.—Commended as well adapted for the purpose intended.**451. Royal Saxon Fire Extinguisher Co., Leipsic, Germany.**

FIRE EXTINGUISHING APPARATUS.

Report.—Commended as good and efficient apparatus for the purpose intended.**452. Louis Wertheim, Bornheim, near Frankfort-on-Main, Germany.**

PACKING.

Report.—Commended for having exhibited packing of very good and solid workmanship.

453. Emanuel A. R. Blancke, Frankfort-on-Oder, Germany.

INDIA RUBBER AND ARMATURES.

Report.—Commended for having exhibited good packings, combining fibrous materials with india rubber in a very convenient way.

454. C. Otto Gehrckens, Hamburg, Germany.

STUFFING BOXES.

Report.—Commended for having exhibited well-executed mineral packing, in which are applied improvements in the arranging of the fibrous parts surrounding the mineral ones.

455. Schaffer & Budenberg, Buckau, near Magdeburg, Germany.

MANOMETERS, COUNTERS, REGULATORS, AND OTHER IMPLEMENTS.

Report.—The exhibit shows a very complete series of measuring implements to be used in testing and surveying steam engines and boilers; the implements are of simple but substantial construction, and give very satisfactory results.

456. A. Bickers & Son, Rotterdam, Netherlands.

HAND FIRE ENGINE.

Report.—A fair exhibit of a hand fire engine.

457. Prakke Brothers, Eibergen, Netherlands.

LEATHER BELTING AND RAW HIDE ROPE.

Report.—Commended for the exhibit of excellently finished belting made from thoroughly tanned leather, and of raw hide rope of good material and construction.

458. Naeff Brothers, Lochem, Netherlands.

LEATHER AND HAIR BELTING.

Report.—Commended for the excellence of the specimens of pliable hair, and oil-tanned leather belting adaptable for use in wet locations, also of the finely finished leather belting made from thoroughly tanned leather.

459. C. Blunck, Christiania, Norway.

CAST-IRON FOUNTAIN AND CAST-IRON PUMPS.

Report.—An excellent display of well-made cocks, valves, and pumps of various kinds.

460. C. Blunck, Christiania, Norway.

PUMPS, FIRE ENGINES, COCKS, AND VALVES.

Report.—A good exhibit of its class.

461. Klem Hansen & Co., Trondhjem, Norway.

WALRUS BELTING.

Report.—This material is from twelve to sixteen thirty-seconds of an inch thick. A strip three inches wide tested in Riehlé's machine gave way at forty-one hundred and seventy-five pounds. Tested for friction over a pulley of fifteen and three-quarter inches extreme exterior diameter, six inches wide, and under a strain of fifty pounds at either end of the belting, the belting slipped, with hair side down, at thirty-eight pounds, and with

flesh side down at eighty-eight pounds. Excellently tanned, and suited by reason of its open texture for reception of oil and emery, and its thickness and elasticity for polishing bands.

462. Kockum Machine Manufacturing Co., Malmö, Sweden.

STEAM ENGINES.

Report.—The exhibited engines are of substantial and very reliable construction, and show good workmanship.

463. C. R. Runqvist, Stockholm, Sweden.

STEAM ENGINE AND GOVERNOR.

Report.—The governor exhibited is of a novel principle, and has the advantage of giving a very powerful energy.

464. Koping Mechanical Works Co., Koping, Sweden.

CAST-IRON CYLINDERS FOR A SIXTY HORSE POWER MARINE STEAM ENGINE.

Report.—The exhibited cylinders, though rather complicated in their forms, are excellent castings, and show on their bored-out inner surfaces not the least imperfection of material.

465. W. Wiklund, Stockholm, Sweden.

ROTARY PUMP AND HAND FIRE ENGINE.

Report.—Rotary pump commended as an excellently designed and well constructed example of its class; also the fire engine for common use.

466. Kristinehamn Machine Manufacturing Co., Kristinehamn, Sweden.

MARINE STEAM ENGINE.

Report.—The engine is in plan, materials, and workmanship of the first class, well devised and invented in all its details for the objects in view.

467. Motala Iron and Steel Works, Motala, Sweden.

COMPOUND MARINE ENGINE.

Report.—The compound marine engine exhibited is in plan, materials, and workmanship of the highest order. The exhibit is a fine specimen of machinery for the purpose intended.

468. Silsby Manufacturing Co., Seneca Falls, N. Y., U. S.

ROTARY STEAM FIRE-ENGINE AND HOSE CARTS.

Report.—Good exhibit, highly finished; good construction and material.

469. Silsby Manufacturing Co., Seneca Falls, N. Y., U. S.

ROTARY STEAM PUMP.

Report.—Commended as a well-designed example of its class, constructed in a superior manner.

470. Colt's Patent Fire-Arms Manufacturing Co., Hartford, Conn., U. S.

STEAM ENGINES, STEAM CYLINDER IN BOILER, INTERCHANGEABLE PARTS.

Report.—The Baxter Portable Engine constructed and exhibited by the Colt's Manu-

facturing Company is in materials and workmanship of the first class. By its plan of placing the cylinder on the top of the boiler, the temperature of the steam in the cylinder is sustained. The parts, being machine-made, are duplicates, and can be used interchangeably in construction and repair.

471. Baxter Steam-Engine Co., New York, N. Y., U. S.

STEAM ENGINES.

Report.—Commended for compactness and simplicity of design, in combining the engine with the boiler, great excellence of manufacture, and economy in the use of steam.

SIGNING JUDGES OF GROUP XX.

The figures annexed to the names of the Judges indicate the reports written by them respectively.

W. H. BARLOW, 1, 2, 3, 4, 6, 9, 10, 17, 18, 24, 26, 31, 32, 38, 46, 47, 52, 96, 105, 107, 122, 123, 125, 126, 127, 159, 205, 217, 218, 228, 247, 258, 351, 359, 412.

CHAS. E. EMERY, 5, 8, 12, 14, 16, 19, 21, 22, 27, 28, 29, 30, 33, 34, 40, 42, 43, 51, 53, 91, 95, 102, 106, 108, 112, 115, 120, 121, 124, 128, 130, 131, 134, 135, 136, 137, 138, 140, 141, 142, 143, 144, 145, 146, 147, 148, 175, 179, 209, 215, 226, 230, 239, 240, 242, 255, 277, 318, 319, 326, 328, 330, 332, 334, 335, 336, 342, 347, 348, 352, 353, 354, 359, 360, 363, 372, 380, 386, 387, 388, 389, 390, 395, 396, 399, 400, 402, 403, 414, 415, 417, 420, 421, 425, 427, 431, 436, 437, 438, 439, 440, 441, 442, 447, 457, 458.

N. PETROFF, 7, 11, 13, 15, 20, 23, 25, 37, 44, 48, 50, 93, 94, 98, 110, 116, 118, 119, 132, 194, 204, 206, 207, 208, 211, 216, 227, 233, 235, 236, 249, 256, 257, 314, 315, 316, 317, 329, 331, 344, 345, 350, 361, 365, 366, 383, 384, 401, 405, 426, 428, 434, 459, 460, 465, 469.

CHARLES T. PORTER, 35, 45, 49, 68, 71, 75, 77, 99, 103, 113, 117, 129, 139, 149, 150, 152, 157, 165, 166, 171, 177, 180, 181, 183, 184, 186, 188, 189, 190, 192, 199, 200, 203, 212, 214, 220, 221, 223, 224, 225, 229, 232, 237, 245, 251, 253, 259, 260, 261, 263, 269, 279, 288, 300, 303, 305, 322, 324, 327, 333, 337, 339, 340, 343, 370, 411, 416, 470, 471.

F. REULEAUX, 36, 41, 78, 87, 151, 160, 162, 163, 164, 169, 170, 172, 173, 178, 185, 196, 198, 202, 210, 243, 244, 248, 252, 262, 297, 306, 320, 321, 323, 338, 349, 355, 374, 375, 379, 392, 404, 422, 423, 432, 433, 435, 445, 446, 448, 449, 452, 453, 454, 455, 462, 463, 464.

JOSEPH BELKNAP, 39, 56, 60, 63, 66, 67, 72, 74, 76, 88, 90, 111, 114, 133, 153, 155, 158, 161, 176, 191, 195, 197, 250, 265, 266, 267, 271, 272, 274, 276, 278, 283, 284, 285, 289, 290, 294, 307, 309, 310, 313, 362, 424.

HORATIO ALLEN, 54, 79, 89, 154, 156, 167, 168, 182, 187, 193, 201, 213, 219, 222, 234, 241, 246, 264, 301, 302, 304, 325, 341, 346, 357, 358, 369, 373, 376, 377, 378, 391, 393, 406, 407, 408, 409, 410, 418, 419, 443, 466, 467.

EMIL BRUGSCH, 55, 57, 58, 59, 61, 62, 64, 65, 69, 70, 73, 80, 81, 82, 83, 84, 85, 86, 92, 97, 100, 101, 104, 109, 174, 231, 238, 254, 268, 270, 273, 275, 280, 281, 282, 286, 287, 291, 292, 293, 295, 296, 297, 298, 308, 311, 312, 356, 364, 367, 368, 371, 381, 382, 385, 394, 398, 413, 429, 430, 444, 450, 451, 460, 468.

E. N. HORSFORD, 461.

SUPPLEMENT TO GROUP XX.

REPORTS OF JUDGES ON APPEALS.

JUDGES.

JOHN FRITZ, Bethlehem, Pa.
EDWARD CONLEY, Cincinnati, Ohio.
CHARLES STAPLES, JR., Portland, Me.
BENJ. F. BRITTON, New York City.
H. H. SMITH, Philadelphia, Pa.

COLEMAN SELLERS, Philadelphia, Pa.
JAMES L. CLAGHORN, Philadelphia, Pa.
HENRY K. OLIVER, Salem, Mass.
M. WILKINS, Harrisburg, Oregon.
S. F. BAIRD, Washington, D. C.

1. Vulcanized Fibre Co., Wilmington, Del., U. S.

CONDENSER FERULES, WASHERS, AND SHEET GOODS OF VULCANIZED FIBRE.

Report.—Commended for excellence in manufacture and adaptability to their intended purposes.

2. Nathan & Dreyfus, New York, N. Y., U. S.

INJECTORS AND EJECTORS.

Report.—Simplicity and efficiency of injectors and ejectors combined in a degree worthy of special commendation.

3. R. D. A. Parrott, Greenwood Iron Works, Orange County, N. Y., U. S.

MINERAL WOOL.

Report.—Indestructibility; value as a non-conducting material for protection against fire and prevention of radiation of heat.

4. John A. Haase, Philadelphia, Pa., U. S.

RATCHET DRILLS AND HOSE SHIELD.

Report.—The ratchet drills are good, well-made articles. The hose shield is a useful device for the protection of fire engine hose from injury from vehicles.

5. McConn & Phillips, Philadelphia, Pa., U. S.

"ROCK" EXPANSION JOINT FOR STEAM PIPES.

Report.—An efficient device to compensate for the expansion and contraction of long lines of pipe.

6. Rufus F. Clark, Boston, Mass., U. S.

EUREKA LUBRICATOR.

Report.—An ingenious device to feed oil to steam cylinder in graduated quantities.

7. Polytechnic School, Boolag, Egypt.

IRON AND BRASS TOOLS AND MACHINE DRAWINGS.

Report.—A fine exhibit, showing the advance of the scholars in this department.

8. Lion & Guichard, Paris, France.

MANOMETER AND PYROMETERS.

Report.—Good workmanship, and fitness for their intended purposes.

9. Valero Cases, Valencia, Spain.

PORTABLE STEAM ENGINE.

Report.—Commended for the following reasons, viz., compact arrangement, and good finish of details, and general excellence, and also for its novelty, as engines of this description are seldom or never condensing ones.

10. Valero Cases, Valencia, Spain.

CHAIN PUMP.

Report.—Commended for simplicity, efficiency, and cheapness.

11. Julius Hock & Co., Vienna, Austria.

PETROLEUM MOTOR.

Report.—Commended for good workmanship, and adaptability to its intended purpose.

SIGNING JUDGES OF SUPPLEMENT TO GROUP XX.

The figures annexed to the names of the Judges indicate the reports written by them respectively.

CHARLES STAPLES, JR., 1, 3, 4, 5, 8, 9, 10, 11.

CHARLES T. PORTER, 2.

COLEMAN SELLERS, 6.

JOSEPH BELKNAP, 7.

